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Success stories from 1995 that recognize the accomplishments and combined effort of Wright Laboratory scientists and engineers. Stories have been selected from the following categories: TECHNOLOGY TRANSITION -- Technology that has achieved application on a Department of Defense system in development or operation or that has provided "quick-reaction" response to problems or needs of field organizations; TECHNOLOGY TRANSFER -- Technology that has transferred from the laboratory to the private sector, to include: industry, academia, and state and local governments; TECHNICAL ACHIEVEMENT -- Major innovative technological advancements that offer significant potential for existing and future Air Force systems; and, PEER RECOGNITION -- External awards or recognitions by the scientific community at large.

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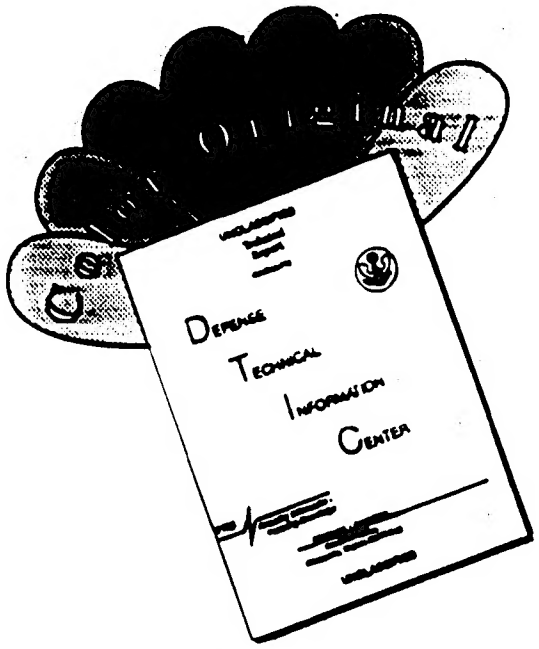

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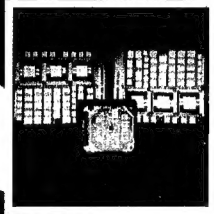

WRIGHT LABORATORY

FORCE MATERIEL CO

UTICAL SYSTEMS CENTER

AR

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A Message About Wright Laboratory Success Stories

At Wright Laboratory, we work as a creative team that builds on the Wright Brothers' heritage. For more than 65 years, the aeronautical architects at Wright Laboratory have created technology advances that have enabled our Air Force to establish and maintain its acknowledged position as the most technically advanced and capable in the world. Today we pursue vital aerospace research and advanced developments in materials, avionics, aero propulsion and power, flight dynamics, solid state electronics, munitions and integrated manufacturing. We are committed to meeting the needs of our fighting forces while offering "dual use" potential in the commercial sector.

We are proud of our people and the teams they have formed, not only to do world-class research but also to transition that technology to meet our customers' needs. In recognition of their accomplishments, each year we highlight some of the best and brightest of our laboratory efforts with "Success Story" profiles. These brief profiles of ongoing research and development projects offer a snapshot look at the breadth and depth of ongoing work at the Air Force's Wright Laboratory. I invite you to explore just a little of the diverse, exciting and innovative work ongoing at the Wright Laboratory during 1995.

Should you see a Wright Laboratory "Success Story" you want to know more about, I hope you will contact us so we might share the details. Also, take a moment to check out our home page on the world wide web (at http://www.wl.wpafb.af.mil).

Richard W. Davis
Colonel, USAF
Commander
Wright Laboratory

WRIGHT LABORATORY
SUCCESS STORIES

Table of Contents

TITLE	PAGE
Introduction	iv
Full Envelope Multivariable Flight Control System Design Approach Recipient of Award	1
Cockpit Evaluation Improves C-141 Cockpit Design	3
Carbon-Carbon Turbine Rotors ImproveTurbine Engine Performance	5
Cooperative Research and Development Agreement (CRDA) to Develop High-Speed, High-Resolution Video Camera	7
New Composite Materials Improve Radomes and Antenna Windows for Missiles and Re-Entry Vehicles	9
New Instrument Developed for Measuring Dissolved Oxygen in Aviation Fuel	11
New Process Makes High Temperature Ceramic Bearings Self Lubricating	13
New Materials System Process Opens Door to Expanded Applications for Holograms	15
New Fiber Coating Process Will Reduce Materials Costs for High Temperature Components	17
High School Apprenticeship and Career Development Programs Help Students	19
New Propellant Charge Fabrication Process for Cased Telescoped Ammunition	21

(Continued on next page . . .)

TITLE	PAGE
New Coating Process Provides Lightweight Solution for Humidity Protection of Integrated Circuits	23
Integrated Product Development (IPD) Principles Used to Design Jet Engine Nozzles	25
Improved 40mm Ammunition Fuze for Special Operations Gunships	27
New Concept Makes Intelligent Electrical Load Management Widely Applicable	29
High-Speed Microchip Lasers Developed	31
Tri-Service Miniature Inertial Measurement Unit (IMU) Selected as Baseline	33
Rapid Foundry Tooling System Automates Pattern Design for Foundry Castings	35
Improved Hybrid Ball Bearings Offer Increased Service Life	37
Thermochemically Actuated Motion (TCAM) Valve Actuator Technology Demonstrated	39
40th Anniversary of the NT-33A In-Flight Simulator	41
Proximity Sensor Tested for General Purpose Bombs	43
The New Laser-Based Sensor Provides Real-Time Control of High-Temperature Coating Process	45
New Production Process for Complex Semiconductors Permits Reduced System Size, Improved Performance	47

TITLE	PAGE
New Production Process Improves Power Density, Reduces Size of Complex Semiconductors	49
Propulsion Controlled Aircraft Technology Selected for 1994 R & D 100 Award	51
Low Infrared Coating Program Provides Interim and Long-Term Solutions	53
Advanced Semiconductor Material Can Improve Performance of Near-Infrared Solid State Lasers	55
Award for Contributions to Ceramic Matrix Composites Development	57
New Photo-Electric Analysis Technique of Pseudomorphic Transistors	59
In-Situ Control of Crystal Growth Advances Semiconductor Laser Technology	61
Linear Motion Oven (LIMO) Provides Critical Advances in Semiconductor Crystal Growth	63
New Fire Fighting Foam Contains Non-Toxic Chemical Component	65
New Insulating Process for Semiconductors Could Lead to Higher-Powered, More-Compact Integrated Circuits	67
Diamond-Coated Ball Bearings Last 100 Times Longer Than Steel Bearings	69
New Source for Growth of Advanced Transistor Materials	71

(Continued on next page . . .)

TITLE	PAGE
Wright Laboratory Team Receives Award for Halon Replacement Contributions	73
Nondestructive Technique for Evaluation of Free Carrier Concentration and Dislocation Density in Doped Gallium Arsenide (GaAs)	75
Microwave Chemical Vapor Infiltration (MWCVI) Process Improves Ceramic Matrix Composite Parts	77
Intelligent Control of Coating Process for Lightweight Turbine Engine Components Improves Thermal Protection	79
Electrically Powered Actuation Design (EPAD) Validation Flight Test Program Team Receives Laurels	81
Materials Research Provides Quick Solution to F-15 Fuel Leakage Problem	83
150 Kilowatt Laser Reduces Cost of Composite Material Thermal Testing	85
Integrated Toolkit and Methodology (ITKM) for Aerospace Manufacturing Developed	87
Scanning Radiometric Imager (SRI) System Characterizes Canopy Laser Scatter	89
Insensitive Explosive Mixture Makes Bombs Safer	91
Air Force Office of Scientific Research (AFOSR) Star Team Award	93

TITLE	PAGE
Fuel Leakage Problem on Aircraft Ground Power Generation System (GPGS) Units Solved	95
Titanium Matrix Composite Reduces Weight of F-22 Aircraft	97
Carbon-Carbon Composite Allows Use of More Efficient, Lighter Batteries for Space Systems	99
Waveguide Laser Combines Small Size, Precision Operation and Lower Cost	101
Improved Crystal Growth Technique Provides More Reliable Laser Source	103
New Laser Particle Counter Sensor Improves Semiconductor Device Yields	105
Antenna Wavefront Simulator (AWFS) Evaluates Current and Future Antenna Electronics Systems	107
Flow Field Enhancers Improve Aircraft Controllability	109
Aircraft Robotic Paint Stripping System Protects Environment	111
TF39 Engine Fan Blade Analysis And Repair Could Save Millions	113
New Composite Material Provides 900 Percent Increase In Operational Life of Aircraft Afterburner Nozzle Components	115
Twenty-Fold Increase in Electro-Optical Crystal Output Achieved	117

INTRODUCTION

Over 280 Air Force Science and Technology "Success Stories" from the Air Force's Wright Laboratory have been presented over the past six years. The individual stories most often represent the combined effort of several scientists and engineers working as a team. The basic and applied research, plus the follow-on technology development described in a "Success Story", are viewed as essential to the continued success of the Wright Laboratory mission.

This year's "Success Stories" were selected from one or more of the following categories:

TECHNOLOGY TRANSITION: Technology that has achieved application on a Department of Defense system in development or operation or that has provided "quick-reaction" response to problems or needs of field organizations (see Table I).

TECHNOLOGY TRANSFER: Technology that has transferred from the laboratory to the private sector, to include: industry, academia, and state and local governments (see Table II).

TECHNICAL ACHIEVEMENT: Major innovative technological advancements that offer significant potential for existing and future Air Force systems (see Table III).

PEER RECOGNITION: External awards or recognitions by the scientific community at large, concerning technology advancements in the areas of Technology Transition, Technology Transfer or Technical Achievement (see Table IV).

To receive more information on the "Success Stories" contained in this document by the experts involved, or to learn about other activities at Wright Laboratory, please contact: WL/DOR, 2130 Eighth Street, Suite 1, Wright-Patterson AFB OH 45433-7542, Tel. (513) 255-4119 or fill-in, and send us the reply card located in the back of this brochure.

TABLE I. TECHNOLOGY TRANSITION SUCCESS STORIES

Success Story Title	*Page #*
Cockpit Evaluation Improves C-141 Cockpit Design	3
New Propellant Charge Fabrication Process for Cased Telescoped Ammunition	21
Integrated Product Development (IPD) Principles Used to Design Jet Engine Nozzles	25
Improved 40mm Ammunition Fuze for Special Operations Gunships	27
New Concept Makes Intelligent Electrical Load Management Widely Applicable	29
Tri-Service Miniature Inertial Measurement Unit (IMU) Selected as Baseline	33
Rapid Foundry Tooling System Automates Pattern Design for Foundry Castings	35
40th Anniversary of the NT-33A In-Flight Simulator	41
Propulsion Controlled Aircraft Technology Selected for 1994 R&D 100 Award	51
Materials Research Provides Quick Solution to F-15 Fuel Leakage Problem	83
Insensitive Explosive Mixture Makes Bombs Safer	91
Fuel Leakage Problem on Aircraft Ground Power Generation System (GPGS) Units Solved	95
Titanium Matrix Composite Reduces Weight of F-22 Aircraft	97
Aircraft Robotic Paint Stripping System Protects Environment	111
TF39 Engine Fan Blade Analysis and Repair Could Save Millions	113
New Composite Material Provides 900 Percent Increase In Operational Life of Aircraft Afterburner Nozzle Components	115

TABLE II. TECHNOLOGY TRANSFER SUCCESS STORIES

Success Story Title	*Page #*
Cooperative Research and Development Agreement (CRDA) to Develop High-Speed, High-Resolution Video Camera	7
High School Apprenticeship and Career Development Programs Help Students	19
Twenty-Fold Increase in Electro-Optical Crystal Output Achieved	117

(continued on next page . . .)

TABLE III. TECHNICAL ACHIEVEMENT SUCCESS STORIES

Success Story Title	*Page #*
Carbon-Carbon Turbine Rotors Improve Turbine Engine Performance	5
New Composite Materials Improve Radomes and Antenna Windows for Missiles and Re-Entry Vehicles	9
New Instrument Developed for Measuring Dissolved Oxygen in Aviation Fuel	11
New Process Makes High Temperature Ceramic Bearings Self Lubricating	13
New Materials System Process Opens Door to Expanded Applications for Holograms	15
New Fiber Coating Process Will Reduce Materials Costs for High Temperature Components	17
New Coating Process Provides Light Weight Solution for Humidity Protection of Integrated Circuits	23
High-Speed Microchip Lasers Developed	31
Improved Hybrid Ball Bearings Offer Increased Service Life	37
Thermochemically Actuated Motion (TCAM) Valve Actuator Technology Demonstrated	39
Proximity Sensor Tested for General Purpose Bombs	43
The New Laser-Based Sensor Provides Real-Time Control of High-Temperature Coating Process	45
New Production Process for Complex Semiconductors Permits Reduced System Size, Improved Performance	47
New Production Process Improves Power Density, Reduces Size of Complex Semiconductors	49
Propulsion Controlled Aircraft Technology Selected for 1994 R & D 100 Award	51
Low Infrared Coating Program Provides Interim and Long-Term Solutions	53
Advanced Semiconductor Material Can Improve Performance of Near-Infrared Solid State Lasers	55
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Linear Motion Oven (LIMO) Provides Critical Advances in Semiconductor Crystal Growth	63
New Fire Fighting Foam Contains Non-Toxic Chemical Component	65
New Insulating Process for Semiconductors Could Lead to Higher-Powered, More-Compact Integrated Circuits	67

TABLE III. TECHNICAL ACHIEVEMENT SUCCESS STORIES (CONT'D)

Success Story Title	Page #
Diamond-Coated Ball Bearings Last 100 Times Longer Than Steel Bearings	69
New Source for Growth of Advanced Transistor Materials	71
Nondestructive Technique for Evaluation of Free Carrier Concentration and Dislocation Density in Doped Gallium Arsenide (GaAs)	75
Microwave Chemical Vapor Infiltration (MWCVI) Process Improves Ceramic Matrix Composite Parts	77
Intelligent Control of Coating Process for Lightweight Turbine Engine Components Improves Thermal Protection	79
150 Kilowatt Laser Reduces Cost of Composite Material Thermal Testing	85
Scanning Radiometric Imager (SRI) System Characterizes Canopy Laser Scatter	89
Carbon-Carbon Composite Allows Use of More Efficient, Lighter Batteries for Space Systems	99
Waveguide Laser Combines Small Size, Precision Operation and Lower Cost	101
Improved Crystal Growth Technique Provides More Reliable Laser Source	103
New Laser Particle Counter Sensor Improves Semiconductor Device Yields	105
Antenna Wavefront Simulator (AWFS) Evaluates Current and Future Antenna Electronics Systems	107
Flow Field Enhancers Improve Aircraft Controllability	109

TABLE IV. PEER RECOGNITION SUCCESS STORIES

Success Story Title	Page #
Full Envelope Multivariable Flight Control System Design Approach Recipient of Award	1
Award for Contributions to Ceramic Matrix Composites Development	57
Wright Laboratory Team Receives Award for Halon Replacement Contributions	73
Electrically Powered Actuation Design (EPAD) Validation Flight Test Program Team Receives Laurels	81
Air Force Office of Scientific Research (AFOSR) Star Team Award	93

COCKPIT EVALUATION IMPROVES C-141 COCKPIT DESIGN

Payoff

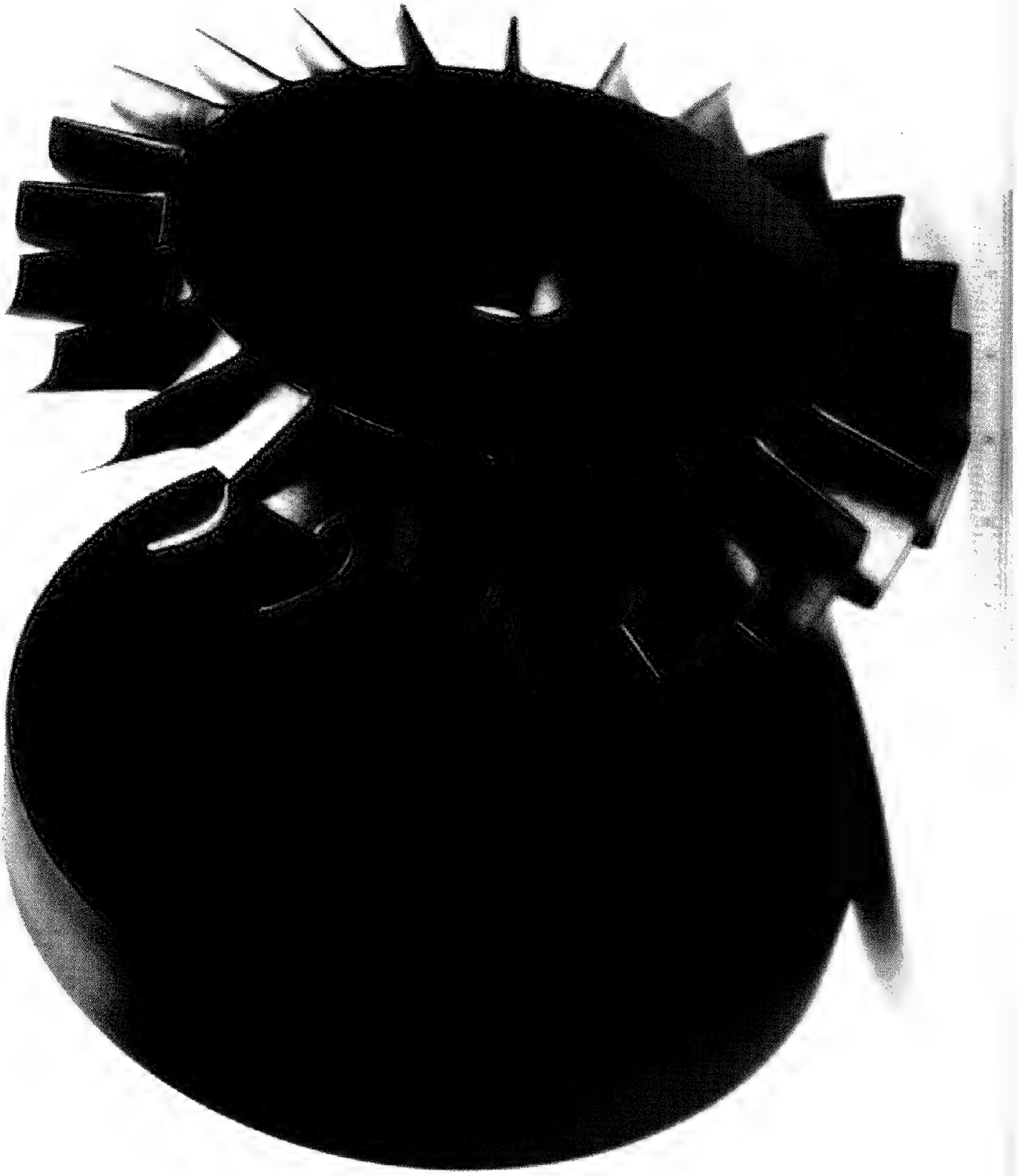
The Flight Dynamics Directorate's quick, cost-effective evaluation, through simulation, of Warner Robins-Air Logistics Center's (WR-ALC) proposed C-141 cockpit design, enabled WR-ALC to meet its acquisition schedule. The recommendations resulting from this evaluation will improve the cockpit design and minimize risk associated with the acquisition of C-141 cockpit modification kits.

Accomplishment

The Flight Dynamics Directorate's Cockpit Integration Division validated a proposed C-141 cockpit upgrade and discovered potential improvements to the new cockpit's design. The rapid cockpit prototyping capabilities of the Division's Crew Systems Integration laboratory, enabled quick, cost-effective evaluations to be performed.

Background

To improve the reliability, maintainability, and affordability of the C-141 aircraft, WR-ALC initiated design modifications to the C-141 cockpit. This included replacing primary mechanical flight control instruments (such as the attitude and horizontal situation indicators) with 6x8 inch color liquid crystal displays. To evaluate the proposed C-141 cockpit modification design, WR-ALC's Cockpit Working Group, capitalizing on its long-standing relationship with the Cockpit Integration Division, requested an independent evaluation, through simulation, comparing the performance of the new cockpit design to the existing C-141 cockpit architecture. Following this evaluation, the software developed for simulation was successfully employed in support of flight test assessment of the new C-141 cockpit design in the Flight Dynamics Directorate's Total Inflight Simulator aircraft. Reuse of the simulation software greatly reduced flight test cost and preparation time.



Carbon-Carbon Turbine Rotors Improve Turbine Engine Performance

Payoff

Uncooled carbon-carbon (C-C) integrally bladed turbine rotors allow turbine engines to run at or near stoichiometric temperatures (ideal fuel/air burning temperatures) providing extraordinary performance benefits compared to state-of-the-art metallic turbines. Using an uncooled C-C turbine can substantially increase expendable engine specific thrust and reduce design and machining costs.

Accomplishment

Under a program sponsored by the Aero Propulsion and Power Directorate, the highest efficiency ever achieved for an uncooled C-C turbine rotor in a turbine engine was demonstrated. Results obtained with the C-C turbine rotor enabled the Directorate to attain the Integrated High Performance Turbine Engine Technology (IHPTET) Turbine Rotor Inlet Temperature (TRIT) goal for uncooled turbines four-years ahead of schedule.

Background

Allied Signal Engines, under contract with the Turbine Engine Division of the Aero Propulsion and Power Directorate as part of the IHPTET program, conducted three tests of an uncooled C-C turbine rotor in a highly modified Joint Expendable Turbine Engine Concept (JETEC) demonstrator. The C-C turbine rotor configurations tested were developed by the Advanced Research Projects Agency (ARPA) under the Extended Long-Range Integrated Technology Evaluation (ELITE) program. The IHPTET program, a joint DoD/NASA/ARPA/ Industry program, has the goal of doubling the propulsion capability of gas turbine engines shortly after the turn of the century. In addition to addressing expendable engines for cruise missiles and standoff weapons via the JETEC program, IHPTET also encompasses turbofan/turbojet engines for fighter/attack aircraft and turboshaft engines for helicopter and transport aircraft. IHPTET goals include increases in thrust/weight ratio, specific thrust, TRIT, and compressor exit temperatures as well as decreases in cost, fuel consumption, and cooling air.

Micro-NIKKOR

Cooperative Research And Development Agreement (CRDA) To Develop High-Speed, High-Resolution Video Camera

Payoff

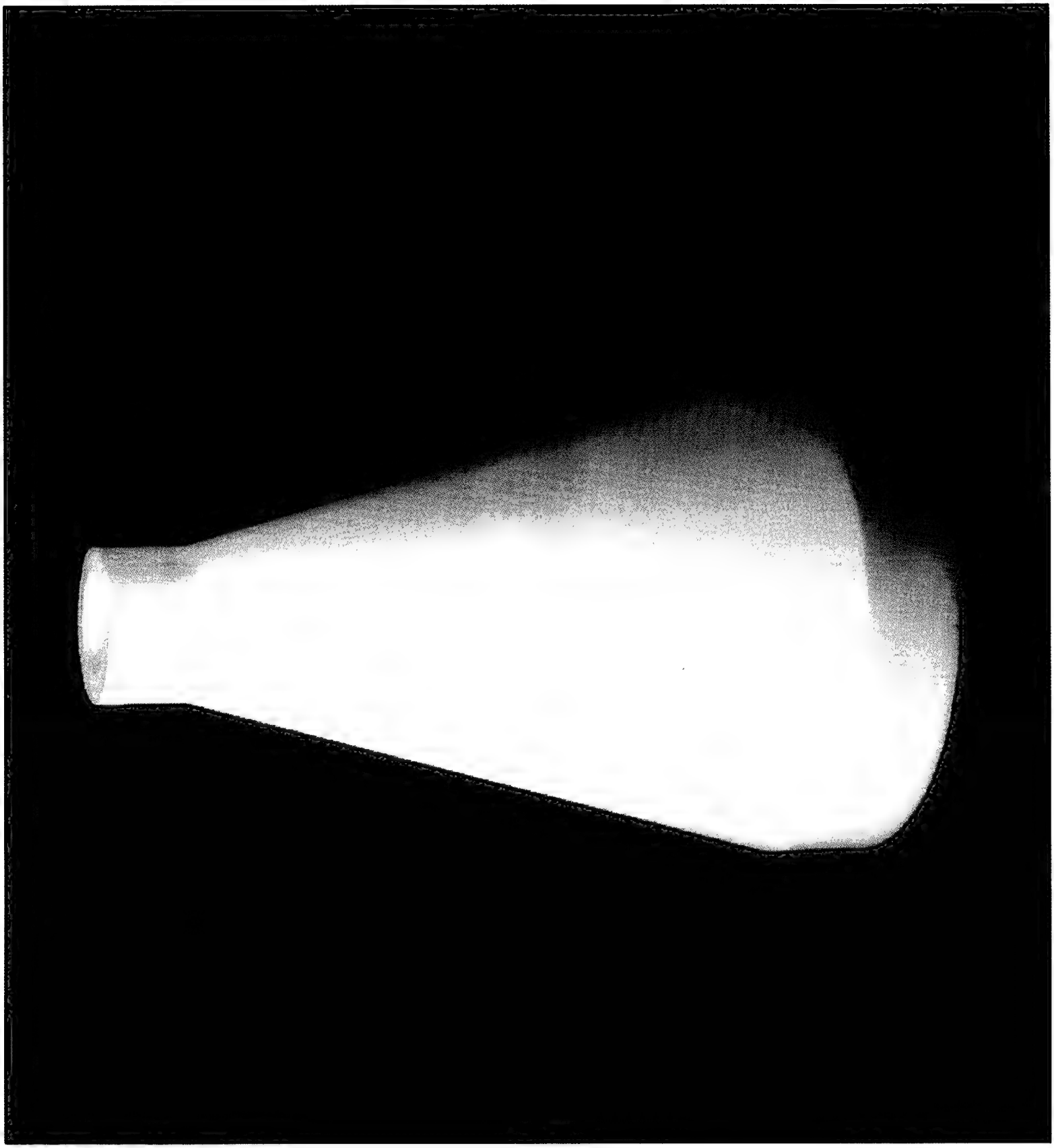
By assisting Adaptive Optics Associates in the development of a high-speed, high-resolution video camera, the Air Force will have a technology available to efficiently record and analyze weapon and airframe performance and the commercial world will have a technology that could be used in manufacturing process control and the medical field. The Armament Directorate's innovative research, facilities and personnel will play a key role in the development of this video camera.

Accomplishment

The Armament Directorate has successfully executed a CRDA with Adaptive Optics Associates, Cambridge MA, for the development of a high-speed, high-resolution video camera that combines the latest developments in electronic imaging technology with state-of-the-art computer technology. This system will have four times better resolution than current electronic imaging systems and captures images at 33 times current high resolution sensor operating rates.

Background

Currently, high-speed film cameras are used by the Air Force to record and analyze weapon and airframe performance. Gathering information on weapon effectiveness, accuracy, tracking and ballistics testing requires very high frame rates on the cameras. To record a single test mission of a weapon released from an aircraft requires as many as 20 high-speed cameras on-board the aircraft with up to 30 high-speed cameras tracking and recording the impact on the target. With all these cameras, vast quantities of high-speed film must be processed and digitized electronically for computer analysis, a task that can take up to two weeks. Since numerous variables can go awry, i.e., over or underexposure, early or late camera triggering, film can jam, etc., the quality of these film data is often unsatisfactory for analysis. In contrast, the new electronic imaging camera, with direct digital data output, will provide an operator feedback system to permit real-time inspection of data quality and operating conditions. When combined with a data link, while the aircraft is still in the air, an analyst on the ground can run computer models to determine whether the desired test objectives have been met, saving valuable and increasingly rare flight test hours. The new electronic imaging system will also have significant environmental impact by reducing the amount of chemical processing currently needed to support film based camera operations.



New Composite Materials Improve Radomes And Antenna Windows For Missiles And Re-Entry Vehicles

Payoff

New composite materials such as the silica fiber reinforced composite used in the test article shown left will produce lighter, more durable and less expensive radomes and antenna windows for missiles and re-entry vehicles. They will extend the service life of radomes and antenna windows and can be used for high temperature commercial applications, such as aircraft engine circuit boards where high temperature performance and thermal stability are required.

Accomplishment

Under a program sponsored by the Materials Directorate, a new family of inorganic resin-based composite materials was developed. These materials are about 20 percent lighter and more durable than conventional ceramics, have excellent high temperature electrical insulation properties, and can be produced using conventional methods and equipment. Using the material to produce in-field replacement antenna windows overcomes moisture absorption and breakage problems associated with traditional materials.

Background

Missile and re-entry vehicle systems have to be able to "see" to function properly. Their "eyes," sensitive radar systems, must be protected from the harsh environment of high speed flight by radomes and antenna windows. Traditional ceramic materials used for these applications lack an optimum combination of mechanical, electrical and thermostructural characteristics. In particular, the high heat conductivities of traditional ceramics results in the need for excessive insulation, subsequent design complexity and high cost. Current re-entry vehicle antenna window materials are brittle and susceptible to damage. The Materials Directorate developed, through a contract with Textron Defense Systems of Wilmington MA, an innovative family of inorganic resin-based composite materials that overcomes the weaknesses of the traditional materials. These materials provide improved ablation (melting or vaporization) performance over current re-entry vehicle antenna window materials and can be fabricated and machined for up to 50 percent less cost than conventional ceramics. Also, the electrical insulation properties of the materials remain stable through high temperature excursions, a characteristic necessary for radar transparency. Radomes and antenna windows fabricated from these new materials possess excellent structural strength, toughness and the ability to survive the severe high temperature and high aerodynamic loads experienced during flight.

New Instrument Developed For Measuring Dissolved Oxygen In Aviation Fuel

Payoff

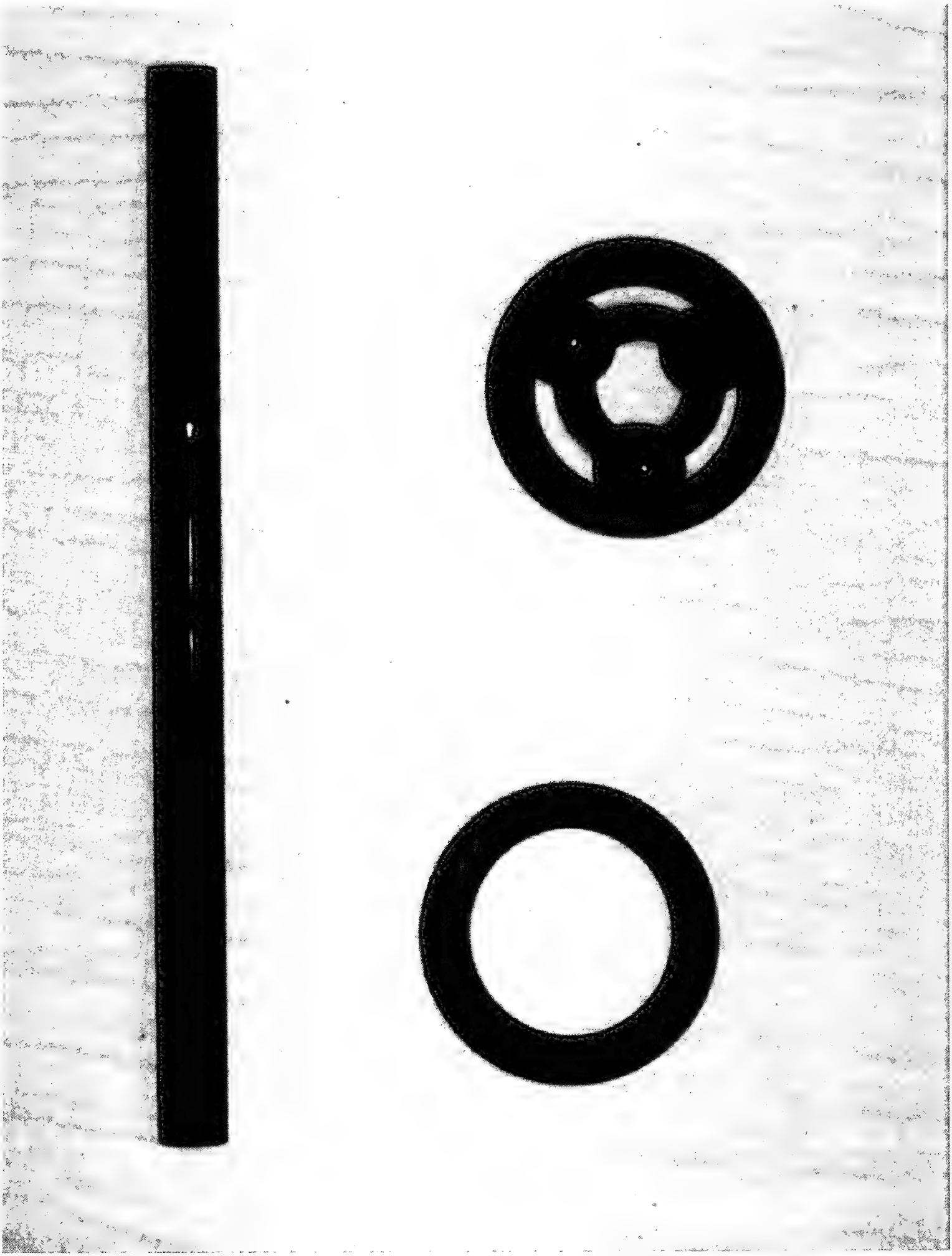
The new laser-based diagnostic technique provides continuous, near-real-time quantitation (precision measurement) of dissolved oxygen in aviation fuel. Increased understanding of dissolved-oxygen chemistry will accelerate the development of advanced fuels and ultimately reduce aircraft downtime due to fuel-system maintenance. The apparatus not only has significant advantages and unique capabilities, but is also more compact and costs $10,000 less than equipment in current use.

Accomplishment

Dr. James R. Gord of the Aero Propulsion and Power Directorate, working with Dr. Steven W. Buckner, an Air Force Office of Scientific Research program participant, developed a new laser-based technique for measuring dissolved oxygen in aviation fuel. The technique precisely measures dissolved oxygen in the natural position without disturbing fuel-flow conditions (nonintrusive) or consuming the sample (nondestructive).

Background

Many aircraft performance improvements are accompanied by substantial heat loads that lead to increased thermal stress on the fuel--the primary coolant for on-board heat sources. The result is increasingly complex thermal management, which affects aircraft design and maintenance requirements. Through studies of aviation fuels and fuel additives, Directorate researchers have identified the critical role of dissolved-oxygen chemistry in fuel thermal stability. A reliable method for measuring dissolved oxygen is essential to continued fuel improvement. The dissolved-oxygen-quantitation technique developed by Dr. Gord offers significant advantages over the gas-chromatograph (GC) approach currently in use. The GC provides two to three oxygen measurements per 15-minute period and consumes the sample. The new laser-based technique provides an oxygen-concentration measurement every 10 seconds or less without consuming the sample. The generation of oxygen-consumption curves requires days with the GC but only minutes with the laser. The technique is ideal for flowing-fuel rigs and has been validated on the Directorate's near-isothermal flowing test rig. It also has tremendous potential for dual-use applications that involve oxygen quantitation in harsh environments.



New Process Makes High Temperature Ceramic Bearings Self Lubricating

Payoff

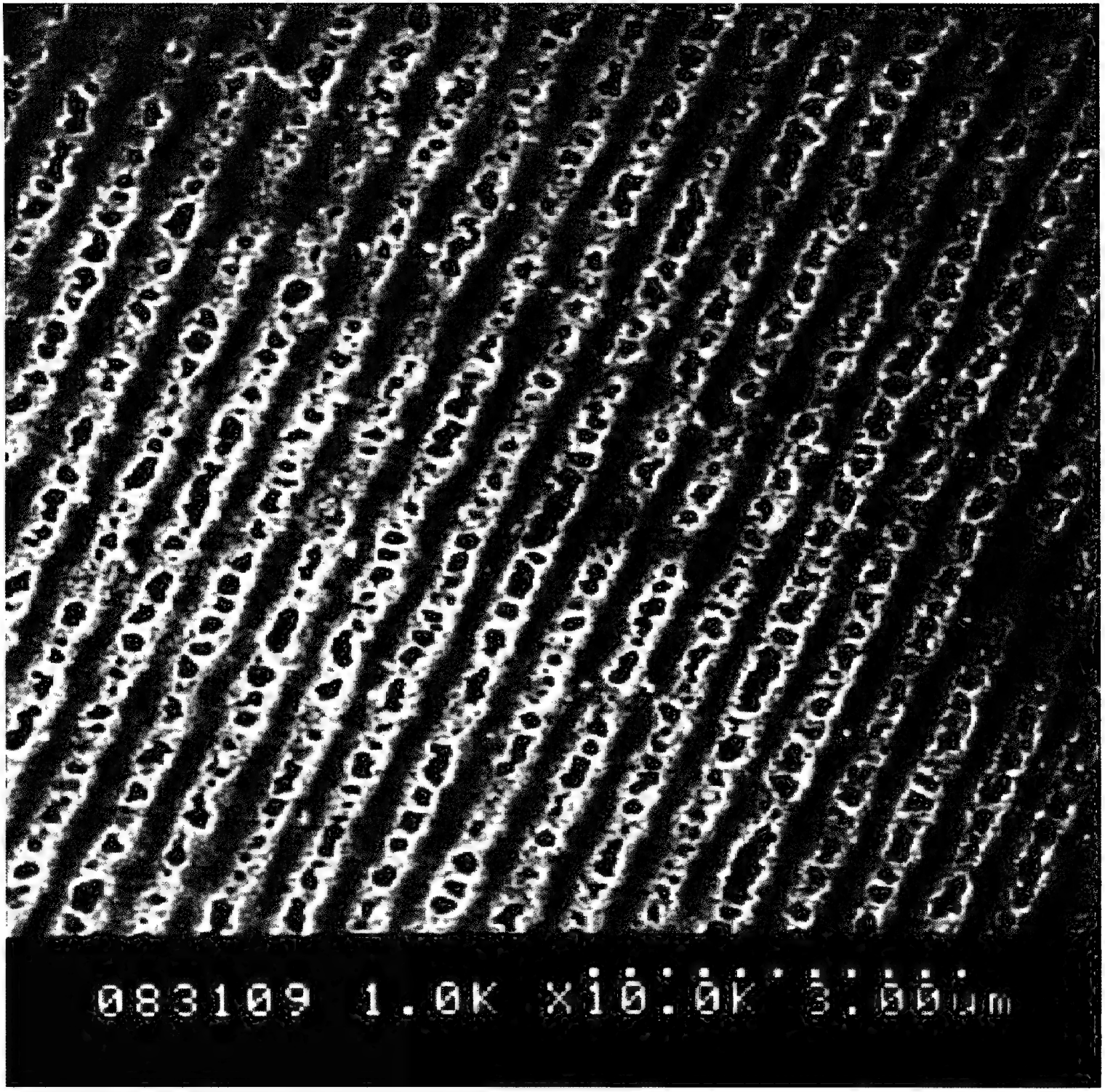
Self lubricating ceramic bearings will allow bearing sumps in expendable gas turbine engines to operate without cooling air and external hardware to supply lubricant to the bearings; thus, providing improvements in engine performance and reductions in engine cost and weight. The inexpensive reaction process used to make a lubricious layer at the bearing surface can be applied to ceramic bearings in a production environment.

Accomplishment

A reaction process developed under a program sponsored by the Aero Propulsion and Power Directorate's Fuels and Lubrication Division enables ceramic bearings to be self lubricating at elevated temperatures. The self lubricating silicon nitride (Si_3N_4) bearings performed for 50 hours in subscale tests at 1250 degrees Fahrenheit and still maintained their critical mechanical properties.

Background

During the last decade, government agencies and industry have expended a significant amount of funds and manpower to develop Si_3N_4 rolling element bearings. High quality Si_3N_4 bearings are available from both domestic and foreign sources. A specific advantage of Si_3N_4 bearings is their high temperature capability. However, to capitalize on this advantage, high temperature lubricants are required. Since 1987, the Fuels and Lubrication Division has tested numerous inorganic compounds in the form of coatings and powders to identify high temperature lubricants for Si_3N_4 ceramics. Of the compounds tested, those containing cesium (i.e., $CsMoOS_3$, Cs_2WOS_3, Cs_2WO_4, Cs_2SO_4 and CsOH) have been particularly impressive. Post test surface analysis of bearing specimens coated with these compounds revealed high levels of silicate (SiO_2) and cesium. This led in-house researchers to postulate that cesium silicates (i.e., $Cs_2O{\bullet}SiO_2$) produced via chemical reactions with the ceramic material are actually the lubricating species. Additional tests conducted in 1993 confirmed that $Cs_2O{\bullet}SiO_2$ is a high temperature lubricant when applied as a coating. In 1994, a small business contract with the Desilube Company of Lancaster PA was modified to develop a process to produce cesium silicates in the matrix of a ceramic surface as a pretreatment for bearing operation. The intended goal was to make a self lubricating layer at the bearing surface while still maintaining the critical mechanical properties of Si_3N_4 throughout most of the substrate material. A patent application has been filed by the Air Force pertaining to cesium silicates as high temperature lubricants.


083109 1.0K X10.0K 3.00µm

New Materials System Process Opens Door To Expanded Applications For Holograms

Payoff

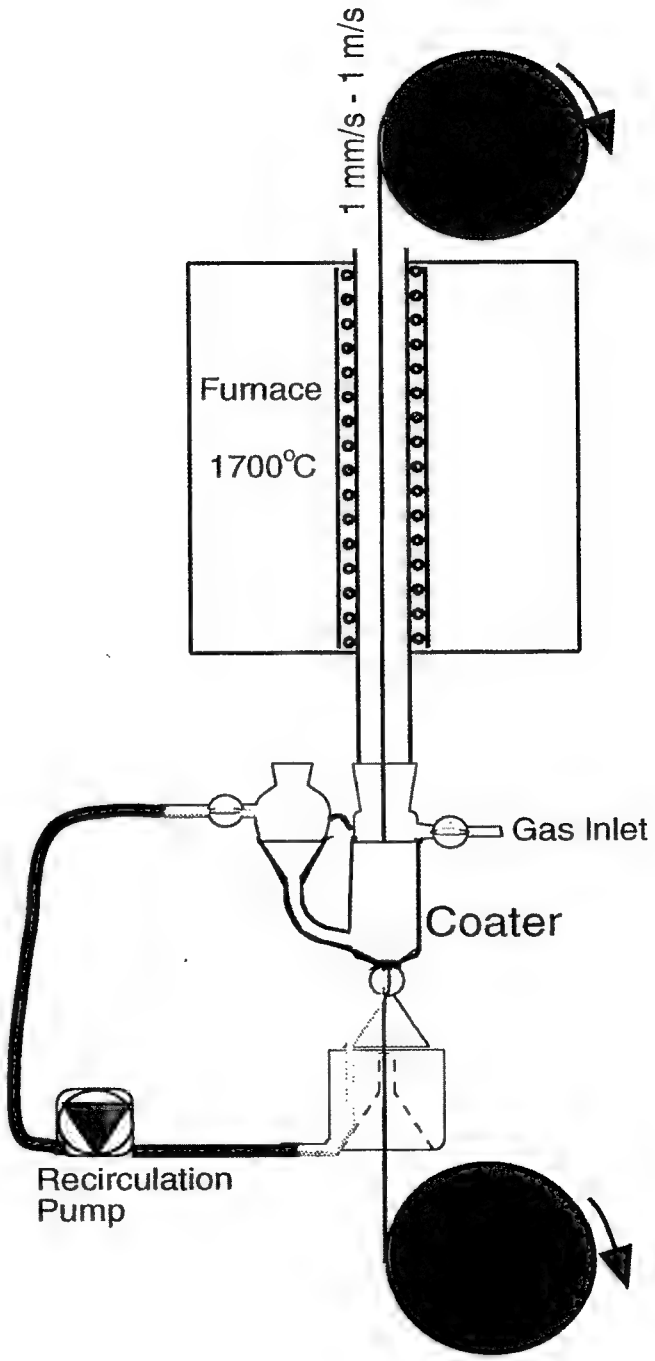
Shown left is an electron micrograph (10,000x) of a volume grating (thick, multi-layered reflecting surface) in a materials system made up of periodic liquid crystal-rich regions (dark) interspersed between polymer-rich regions. Compared to current methods, the time and money to fabricate gratings for electronically switchable holograms will be reduced by 200 percent or more.

Accomplishment

Using conventional methods, Materials Directorate scientists developed a new materials system and single-step process for making advanced holograms (the number of steps needed are reduced from many to one), whose imaging properties can be rapidly and reversibly changed. This patented process makes volume gratings in a unique materials system that, in addition to providing high diffraction efficiency and precise angle control, can be switched on and off electrically. This "switchability" makes possible a number of military and civilian applications.

Background

Hologram technology, dealing with the properties of light, is important to the development of heads-up displays, optical data storage, optical computers and sensor systems. For many of these applications, control over how efficiently laser beams are reflected or split in two by diffraction is required. Several types of gratings (reflecting surfaces) showing efficient diffraction control have been studied, but not all can sufficiently control the angle and efficiency of the diffracted laser light in real-time. Certain applications, such as tunable filters, need both high diffraction efficiencies and precise real-time control of the angles of the diffracted laser light. Usually, volume gratings are produced to obtain these characteristics by an involved procedure requiring many steps. The new one-step process produces volume gratings that not only exhibit efficient diffraction control but are electrically switchable as well. As laser light is directed at the grating, a change in the hologram is produced when low voltage is applied to the hologram. This "switchability" makes possible a number of applications, including special filters that can automatically switch wavelengths to protect valuable sensors from damaging laser radiation, holographic memory devices with rapid electro-optical read-out of different "pages" of information, more versatile heads-up displays for aircraft and commercial super market type bar code scanners that require no moving parts. The new materials system has also led to patenting of a laser dosimeter (detector) badge ready for development. When affixed to a pilot's helmet it could record the laser wavelength and energy dosage in incidents where the pilot is irradiated with unknown laser light. The information gathered would be vital in diagnosing the threat from a hostile laser.


1 mm/s - 1 m/s
Furnace
1700°C
Gas Inlet
Coater
Recirculation
Pump

New Fiber Coating Process Will Reduce Materials Costs For High Temperature Components

Payoff

Shown left is a schematic of the new fiber coating device used for coating continuous fibers in a controlled atmosphere. This device enables the fabrication of high temperature ceramic matrix composite fibers at reduced costs, with fewer pollutants and in less than half the time.

Accomplishment

Materials Directorate scientists developed and patented a new coating apparatus and process that enables coating of continuous fibers used in ceramic matrix composites. Use of this new device allows application of coatings in a controlled atmosphere, so that carbon and metallic coatings can be applied.

Background

Air Force aircraft requirements continually demand more from aerospace materials. They must be lighter and stronger while withstanding higher temperatures. To help meet these demands, composite materials are being used more often in aerospace applications. Certain composites, although tough and strong, cannot withstand high temperatures in air, and require oxidation resistant fibers, matrices, and fiber coatings for use at high temperatures. An oxidation resistant fiber-matrix interface may either be oxidation resistant itself, provided it has the correct mechanical properties, or have a coating that is present during processing but oxidizes away after heat-treatment, leaving a gap that provides the necessary mechanical properties. However, application of a uniform coating to continuous fibers can be difficult, and known techniques for applying coatings, i.e. chemical vapor deposition (CVD), are often expensive, lack versatility and generate pollutants. The usual method for applying such coatings is CVD. However, CVD requires equipment that costs more than $300,000. In comparison, the new coater is not only less expensive ($10,000-$20,000), it applies a coating at speeds typically faster than can be achieved with CVD while generating very little toxic gas. Potential Air Force applications for oxidation resistant coated fibers include composites for turbine engine nozzles, flaps, seals and combusters. The new coater can also be used to coat copper wire for electric motor armatures allowing operation at higher temperatures, and to coat optical fibers for increased durability and internal reflectance.

High School Apprenticeship And Career Development Programs Help Students

Payoff

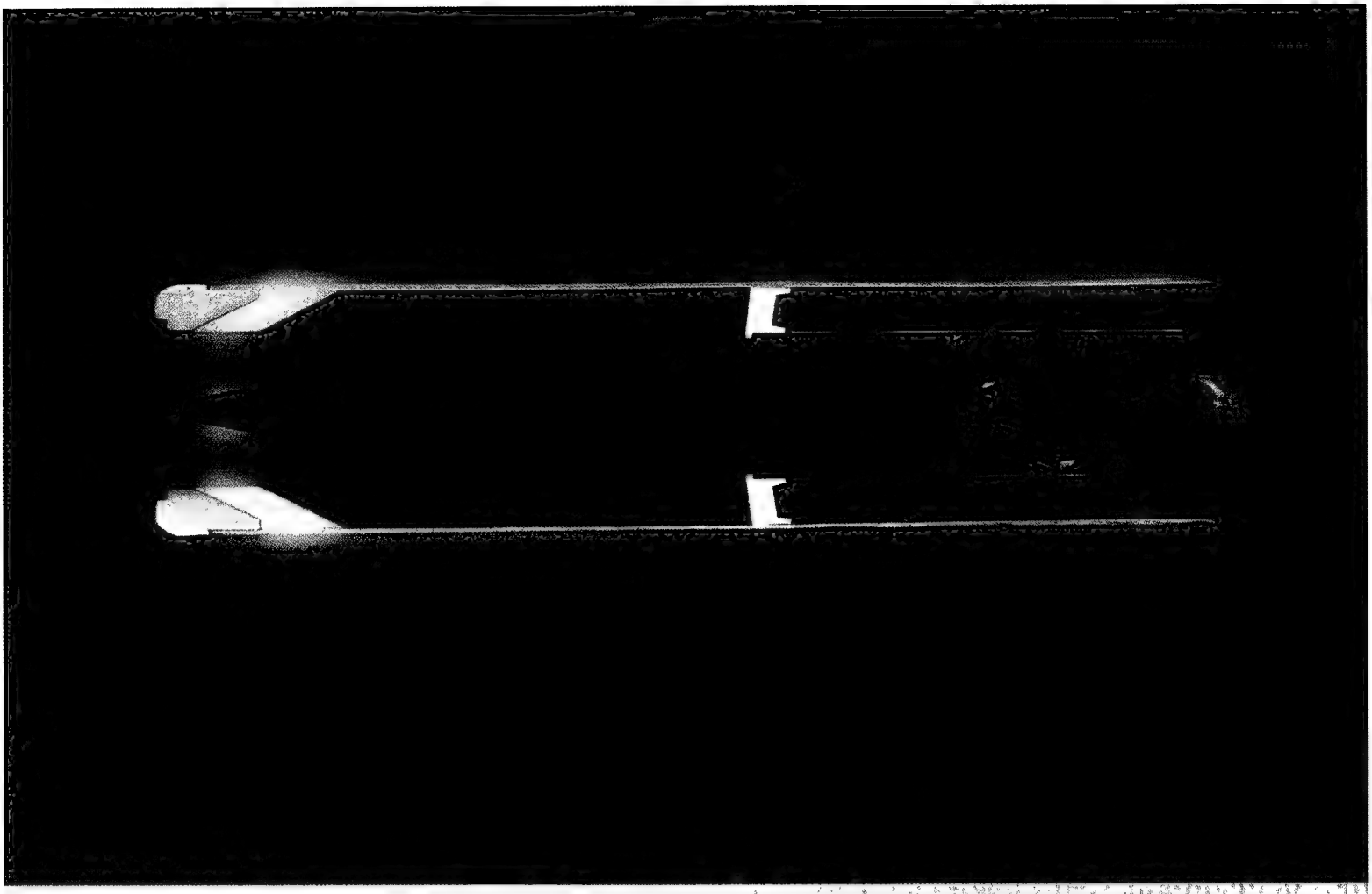
By providing "hands-on" experience to prospective scientists and engineers, the High School Apprenticeship Program (HSAP) and the Career Development Program (CDP) help students in the Eglin Air Force Base area make critical career decisions. The involvement of the Armament Directorate in the programs enhance the "good neighbor" image of the Air Force in the local community.

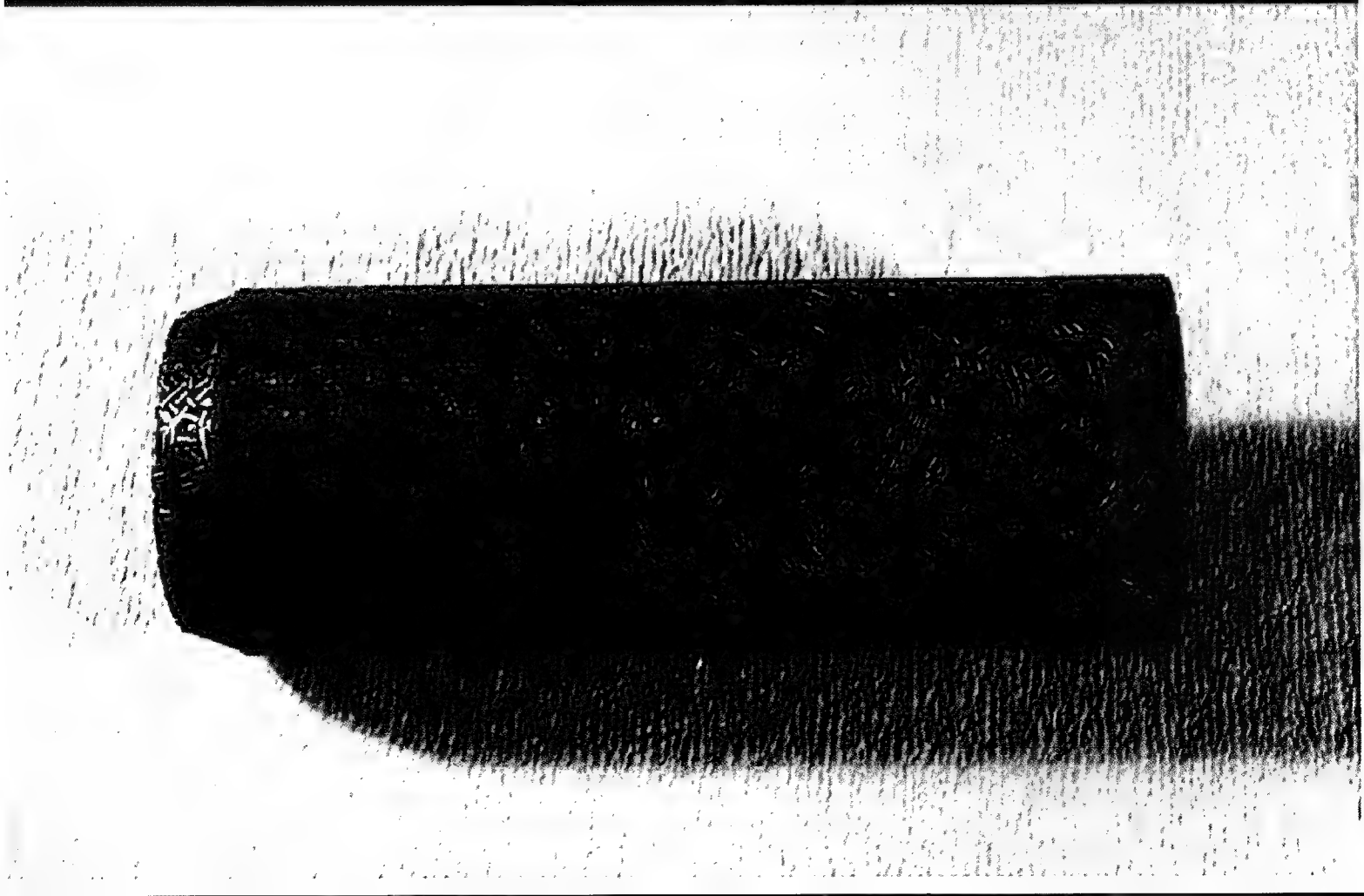
Accomplishment

Each year Wright Laboratory's Armament Directorate sponsors 20-30 gifted student in grades 10-12 from local high schools surrounding Eglin Air Force Base under the auspices of the HSAP and CDP. One-hundred percent of the students involved in the HSAP have gone to college to pursue a science degree, while over eighty percent of those involved in the CDP have gone to college.

Background

The HSAP and CDP, established in 1984 and 1990 respectively, assigns students in paid positions to mentors throughout the Armament Directorate to do research, conduct experiments, learn about science and engineering and present their findings at the end of the summer to Directorate personnel and school officials. Students are selected for the HSAP based on the "whole person" concept showing an overall involvement in academic as well as civic activities. Up to two HSAP slots per year are awarded to regional science fair winners from the local area. The CDP students, besides meeting the same criteria for selection, must also come from economically disadvantaged families. Students apply for the programs through their school guidance counselors. Students are instructed in a variety of areas including scientific programming languages, energetic dynamics, and environmental analysis of soils and plants, and can work throughout their high school years in the program.





New Propellant Charge Fabrication Process For Cased Telescoped Ammunition

Payoff

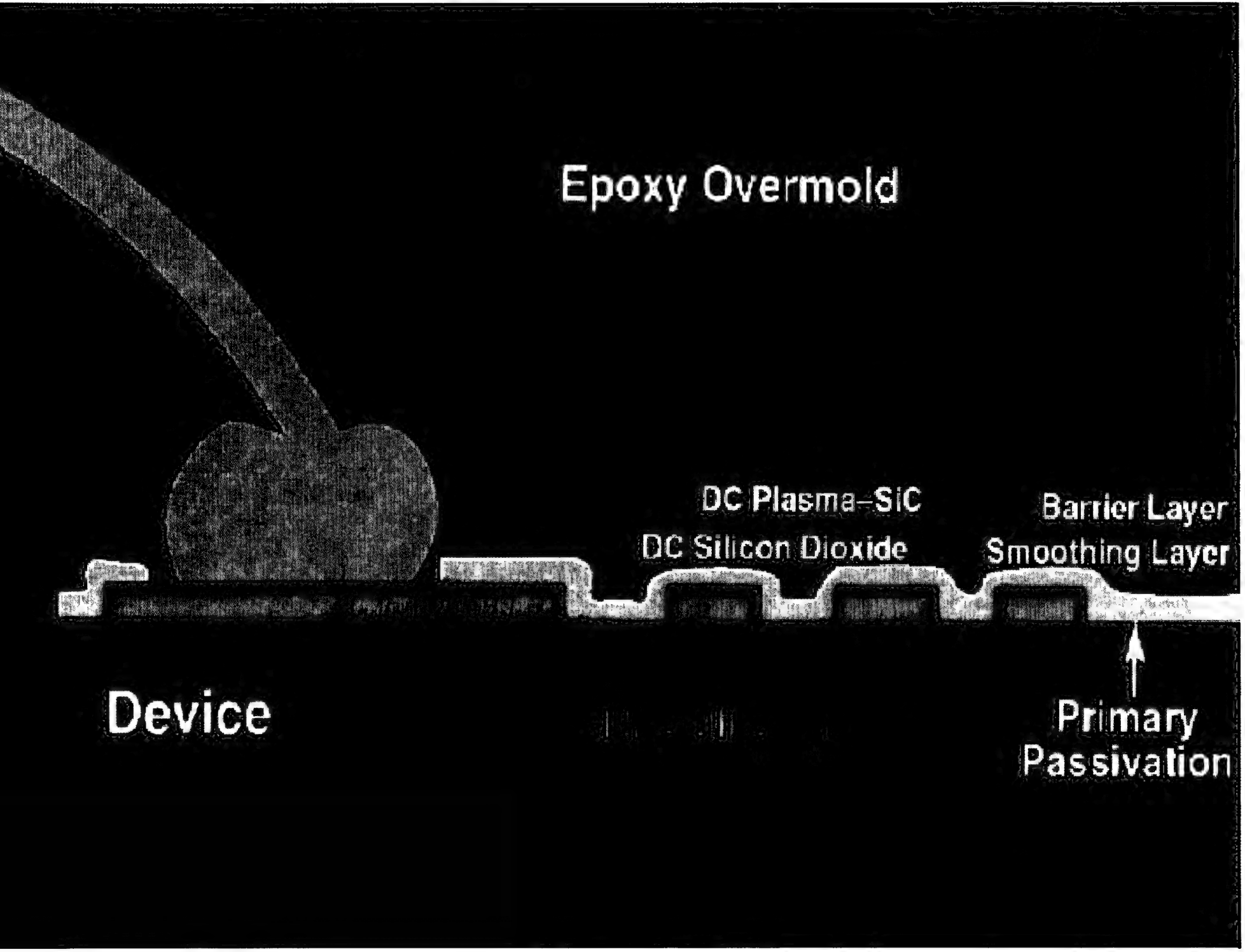
The thermal consolidation of propellant grains into a precise molded charge will significantly reduce the manufacturing cost of propellant charges for cased telescoped ammunition. The technology has been transitioned to the Army's Research and Development and Engineering Center, Picatinny Arsenal NJ.

Accomplishment

Under a program sponsored by the Armament Directorate, an improved propellant charge fabrication process for cased telescoped ammunition was developed. The thermally consolidated propellants produced are of a higher quality and cost less than propellant charges produced using the prevailing fabrication process.

Background

Cased telescoped ammunition contains the projectile inside the cartridge case rather than protruding from the case as with most ammunition. It was developed as part of the Air Force's Advanced Gun Technology program. All telescoped ammunition designs have used propellant charges molded or compressed from granular propellant. This molding or compaction process greatly increases the packing density--which enables more energy to be stored. This increased energy provides higher muzzle velocities. Unfortunately, the prevailing fabrication process is sensitive, time-consuming, dirty and costly. This process uses a solution of acetone, alcohol and water to soften the propellant grains before they are compressed. It requires precise temperature and humidity controls, and up to ten hours of conditioning time to ensure proper ammunition performance. Since the solution leeches the graphite coating from the individual propellant grains, the residue gums up the tooling, which requires extensive downtime for cleaning and maintenance. The Armament Directorate tackled this problem of complex, time-consuming manufacturing through a Small Business Innovation Research program. The new process applies binder to the individual grains of propellants. By heating the propellant grains plus the molds and mandrels used in the compaction process, the grains are easily thermally consolidated into the desired shape and density within five minutes without use of a solvent solution. The thermally compacted cased telescoped ammunition was successfully fired and evaluated during the 20mm Advanced Gun Technology program.


Epoxy Overmold
DC Plasma–SiC
DC Silicon Dioxide
Barrier Layer
Smoothing Layer
Device
Primary
Passivation

New Coating Process Provides Lightweight Solution For Humidity Protection Of Integrated Circuits

Payoff

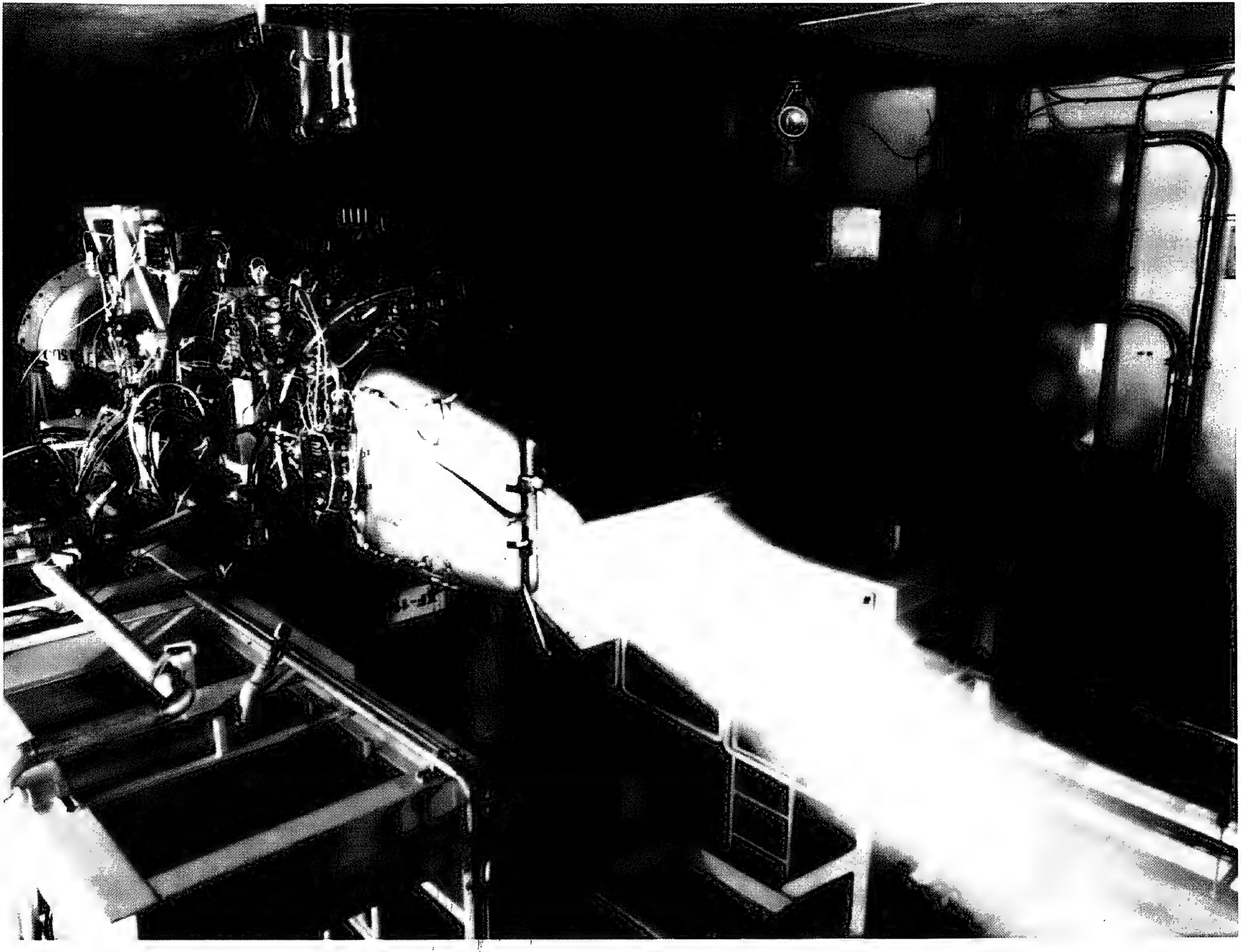
The development of a process for applying a protective silicon carbide ceramic coating to plastic packaged integrated circuits offers circuit manufacturers a lightweight alternative to metal or ceramic cases for protection against humidity-caused corrosion in electronic components. Ceramic thin-film coatings provide greatly improved reliability for plastic packaged electronic circuits while reducing weight by as much as 80 percent from hermetic packaging.

Accomplishment

Under a program jointly sponsored by the Materials and Manufacturing Technology Directorates, National Semiconductor Corporation (NSC) and Dow-Corning developed a process for applying a ceramic coating to integrated circuits prior to plastic encasement. The ceramic coating will boost the protection against humidity-caused corrosion to a level nearly equal to hermetically sealed circuits. This thin-film coating, when applied to partially assembled integrated circuits prior to plastic overmolding, produced sealed chips with significantly enhanced reliability, as compared to standard plastic packages.

Background

Air Force systems, heavily dependent on high density electronic circuits, must perform through a range of environments. An environment of special concern to integrated circuit manufacturers is one of high humidity. Humidity can wreak havoc on electronic circuits, activating ionic impurities that attack the metallization, causing entire components to fail. To provide adequate protection, circuits for years have been enclosed in air tight cases of metal or ceramics. With this packaging approach, overall component weight goes up as the density, sophistication and number of integrated circuits in a component increase. Plastic-packaged electronic components, preferred because they are lighter and less bulky, have been used as a last resort in several cases when hermetic packages were not available. However, plastic-packaged electronic circuits are susceptible to damage by the interaction of excessive humidity and ionic impurities that can lead to component failure. The process developed by NSC and Dow-Corning for protecting integrated circuits prior to plastic encasement involves the application of a ceramic coating consisting of two layers. A silicon dioxide layer is used first for smoothing the circuit topology followed by a silicon carbide layer that acts as a barrier against moisture and activated ion impurities. Using this process offers a lightweight solution for humidity problems in aircraft and automobile electronic systems, hand-held radios and cellular phones.



New Concept Makes Intelligent Electrical Load Management Widely Applicable

Payoff

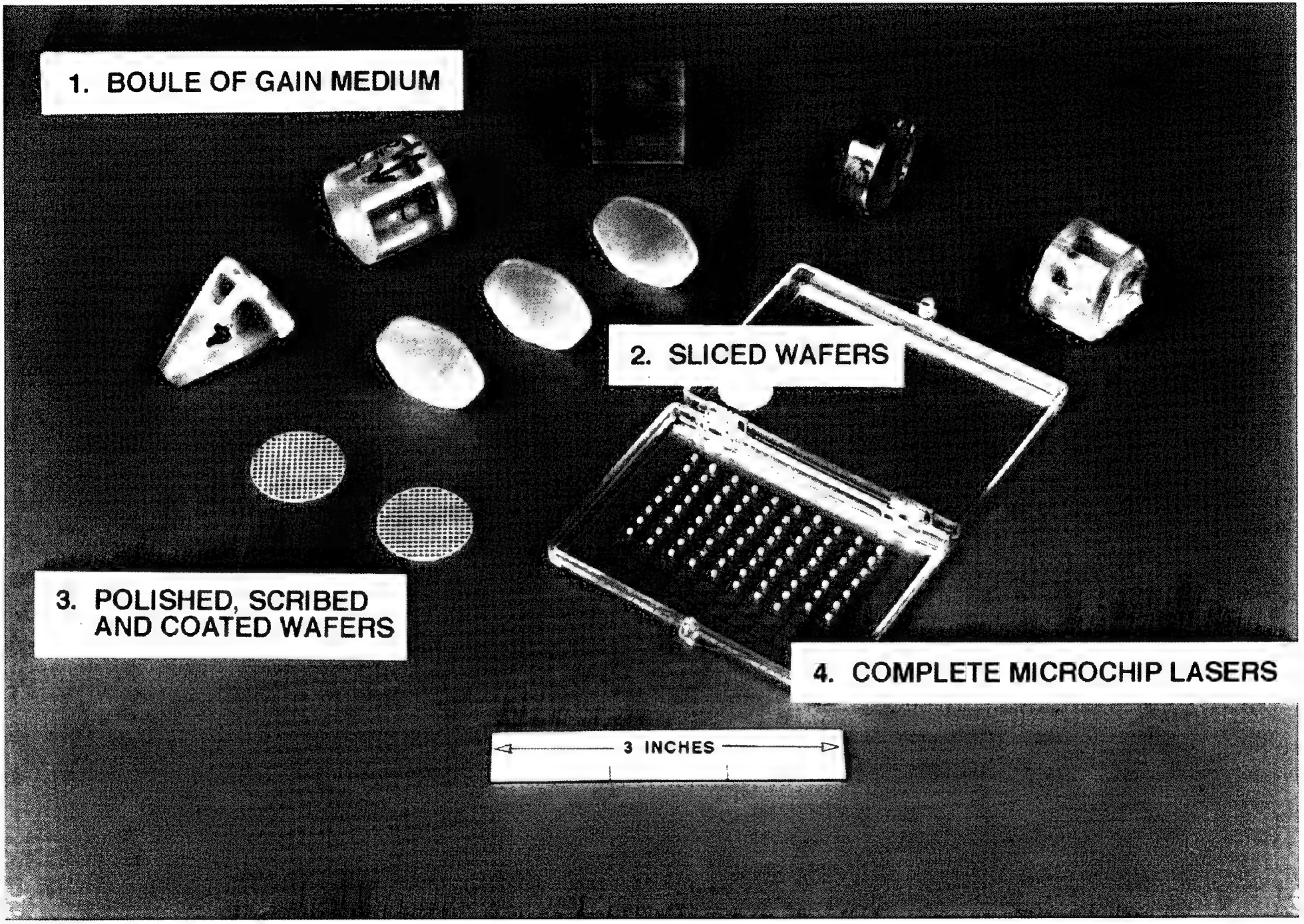
A new electric load management concept, using remote terminals (RT) and a solid state power controller (SSPC), has been selected by Bombardier Aerospace Group - North America for its long range, high-speed global express business jet and by Lockheed Aeronautical Systems Company for the advanced Hercules II, C-130J transport. The RT provides improved diagnostics that contribute to simplified maintenance, improved survivability and lower life-cycle costs. It also increases electrical system fault tolerance and reliability.

Accomplishment

The Aero Propulsion and Power Directorate's Aerospace Power Division has developed new, generic RTs that can be configured to manage any type of aircraft alternating current (AC) or direct current (DC) electrical system. The RT is the heart of an electrical load management system (ELMS) that replaces the conventional circuit breaker/relay panel and provides the intelligence to perform automatic load control and built-in-test.

Background

The key technologies in implementing intelligent electric load management are the RT and the SSPC. The ELMS distributes, controls, and monitors power to all aircraft loads and power busses, and functions as a utility management system for basic airplane subsystems. Once activated, the ELMS automatically performs all load management and electric bus switching control functions through its capability to continuously sense and monitor the health of the vehicle's electrical system. The ELMS is activated in a normal mode which contains flight, ground, and maintenance submodes. In case of an emergency (electrical failures), the ELMS automatically reconfigures the electrical busses, sheds loads if necessary, and simultaneously informs the crew as appropriate. The crew can react by either overriding the ELMS decisions or acknowledge the failure(s) and continuing the mission. These features reduce pilot burden and simplify maintenance procedures. On the C-130J this technology enabled the removal of one person (the flight engineer) from the cockpit which has resulted in a two-person flight crew. The SSPC is a solid state equivalent to a series fuse/relay (circuit breaker) combination that performs the load control (switching) on command from the RT or pilot while providing automatic short circuit protection to the wire and load. An advanced SSPC has demonstrated a six-fold improvement (130 amps, 270 volts DC versus 20 amps, 270 volts DC) over current SSPCs.


1. BOULE OF GAIN MEDIUM
2. SLICED WAFERS
3. POLISHED, SCRIBED AND COATED WAFERS
4. COMPLETE MICROCHIP LASERS
3 INCHES

HIGH-SPEED MICROCHIP LASERS DEVELOPED

Payoff

The new microchip laser technology provides high-performance laser sources which are compact, rugged and mass producible. The nearly perfect beam quality, high-pulse repetition frequency (PRF), and miniature size of the microchip lasers combined with their inexpensive nature make them an ideal choice for use in laser radar systems. Small, high-performance laser radars are essential to developing smaller, less expensive and more powerful seeker components for the next generation of smart munitions.

Accomplishment

Under the sponsorship of the Armament Directorate, Lincoln Laboratories developed low-cost, high-performance microchip lasers that operate at pulse rates up to 2.3 million times per second. This rate is the highest PRF ever recorded for Q-switched solid-state lasers.

Background

A laser radar (also known as a LADAR) consists of a laser source, a laser beam scanner, an optical detector and timing circuits. LADAR constructs a three dimensional image of a target on the ground using the scanner to direct the laser beam to various points in the target scene and timing how long it takes a laser pulse to return to the detector. This 3-D picture allows the weapon to identify the target, track it and guide the munition to it. In the past, laser radars operated too slowly to be used during the terminal guidance portion of the weapon's flight since the PRF of the laser source limits the rate at which LADAR data can be acquired. Increasing the PRF of a laser source enables laser radar seekers to function during high-speed engagements such as in terminal guidance, which is the last few seconds the weapon bears down on its target. Other features of this new technology include highly efficient energy conversion and extremely small packaging--exactly what is required for highly sophisticated, yet compact weapon systems.

TRI-SERVICE MINIATURE INERTIAL MEASUREMENT UNIT (IMU) SELECTED AS BASELINE

Payoff

The tactical grade IMU exhibits the required performance (one degree per hour gyroscopic drift rate), small size (25 cubic inches in size) and low cost (less than $10,000/production unit) that makes it suitable for use as a common core IMU for a variety of smart munition guidance systems such as the Joint Direct Attack Munition (JDAM) guidance system.

Accomplishment

McDonnell Douglas selected the Tri-service Miniature IMU design, developed by Wright Laboratory's Armament Directorate, as the baseline IMU for their competing JDAM guidance system. JDAM is the next generation self-guiding munition that utilizes both a global positioning system satellite receiver (to receive the satellite global positioning system signals) with an IMU (to sense the JDAM's movements in space) for its guidance system. McDonnell Douglas is one of the two competing JDAM prime contractors.

Background

In 1984, the Armament Directorate initiated a program to develop a miniature ring laser gyro (RLG). Since weapon guidance systems such as "smart" munitions need small, compact components in order to fit inside a weapon, a subsequent program, titled the Tri-service Miniature Inertial Measurement Unit, was initiated to incorporate the miniature RLG into a small, inexpensive tactical weapon grade IMU. This tactical weapon grade component is designed to be reliable, yet affordable, since it will be destroyed when the weapon detonates. In 1993, the Air-To-Surface Weapons System Program Office at Eglin AFB FL, conducted the Operational Concept Demonstration (OCD) program. The OCD program successfully demonstrated, via free flight launches of a GBU-15 air-to-surface weapon, that tightly coupled Global Positioning System/IMU navigation could be accomplished. The inertial navigation system used in the OCD modified GBU-15 weapon contained the miniature RLGs developed by the Navigation and Control branch of the Armament Directorate.

Rapid Foundry Tooling System

CASTING INTERFACE

Isometric View

ORIENT ON PATTERN BOARD

ADD OFFSET PARTING

IDENTIFY CORES

SET MOLD PARAMETERS

LOCATE SPRUE

CONSTRUCT RUNNERS

LOCATE RISER

BACKUP

Exit

Components of CASTING-MANA

- CASTING-MANAGER(?)
  - MATCH-PLATE 31976(?)
  - MATCH-PLATE(?)
  - POTENTIAL-PROBLEMS
  - PROBABLE-CAUSES
  - CORRESPONDING-CURES
  - RIGGING(?)
    - riser30956(?)
    - GATE 30452(?)
    - RUNNER 1(?)
    - SPRUE-WELL
    - SPRUE
  - MOLD
    - COPE
    - DRAG
  - PARTING-LINE(?)
    - FRONT-PROFILE11793(?)
    - FRONT-PROFILE11803(?)
    - MAIN-PARTING-LINE
  - PATTERN-BOARD

FBDE DESIGN FBDE GDSII

Rapid Foundry Tooling System Automates Pattern Design For Foundry Castings

Payoff

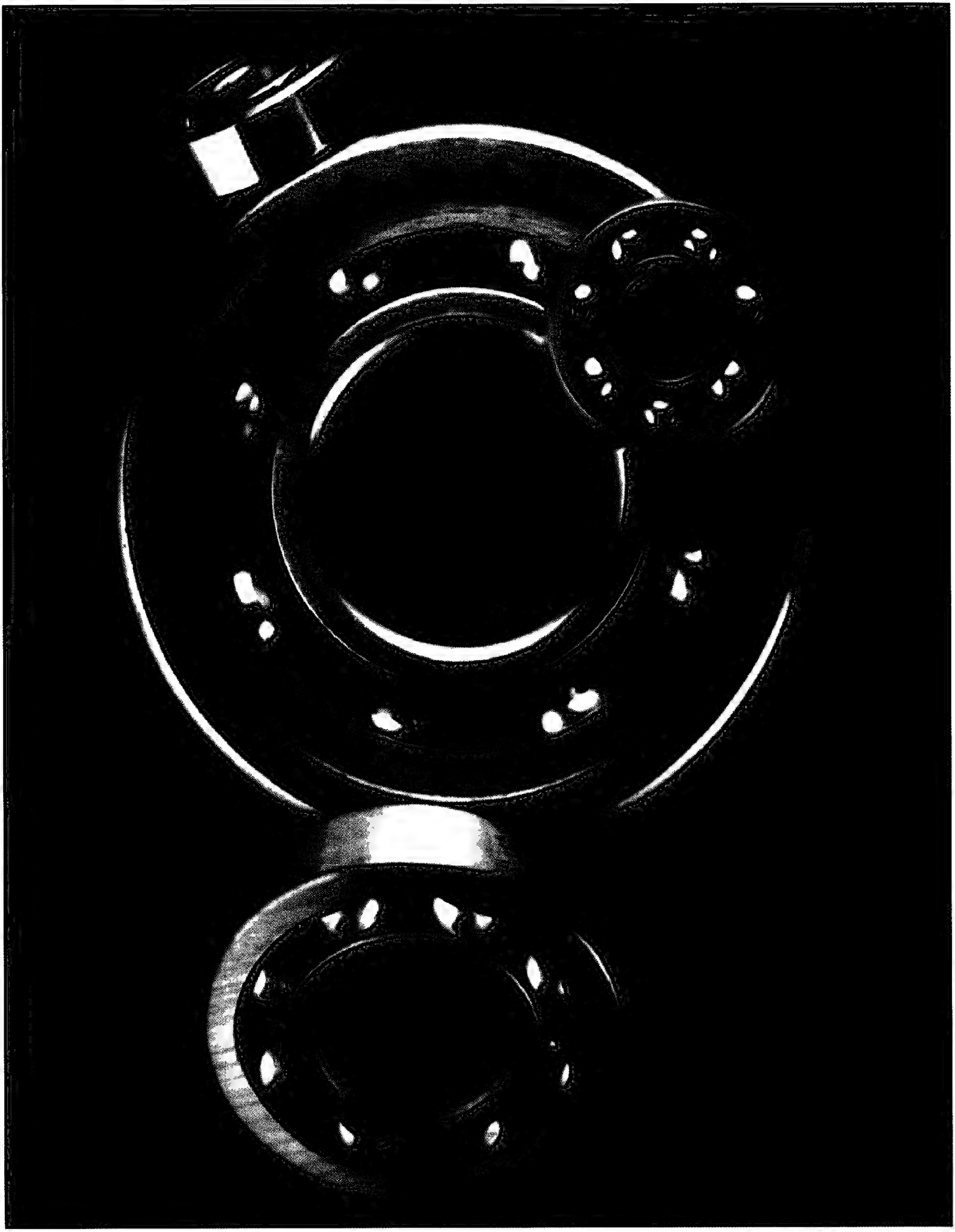
The memory-driven software system reduces the time for design and generation of foundry sand casting patterns from two weeks to less than two days. This system can play a key role in improving the quality and cost efficiency of cast metal parts, a critical factor in complex castings used in Air Force aircraft, missiles and spacecraft.

Accomplishment

Scientists at Wright Laboratory's Materials Directorate and AIWARE, Inc., working together with the San Antonio Air Logistics Center, have developed an automated pattern design system that reduces the time for generating foundry sand casting patterns by as much as 80 percent. Their Rapid Foundry Tooling System brings the power of feature-based geometric modeling to the task of pattern design for cast metal parts.

Background

High volume (100+) structural components of all sizes with complex geometry, and large, low volume mechanical parts are generally more economical to produce by molten-metal casting than via material removal operations. In the sand casting process, a sand mold is created for each new part by packing the sand around a template, called a pattern, which represents the part plus additional geometry for access of the molten metal into the mold cavity. The cost of designing and producing the pattern is very expensive. A pattern maker, in addition to translating the blueprint of a part into a pattern, must also include all the additional process features such as gates, risers, chills, drafts, shrinkage, and so on. Proper placement of these pattern features can impact final part quality by influencing the process. The Rapid Foundry Tooling System improves the overall casting process by employing four modules to bring the power of advanced computer-based information technology to the task of pattern making. First, a feature based design environment is used to translate the blueprint into a solid model of the pattern. Next the system's episodal associative memory relates past experiences of pattern makers with similar parts. These experiences may be applied to the current pattern design in the casting design module, where gates, risers, and other process features are also incorporated. Third, an automated design module uses expert casting knowledge to augment the part model adding process features to the part to create the casting patterns. Finally, a stereolithography output module generates a prototype of the final pattern. The Rapid Foundry Tooling System can also aid in the training of pattern designers. The Rapid Foundry Tooling System is now in use as a prototype at the San Antonio Air Logistics Center to design patterns for a wide range of cast aluminum parts for Air Force aircraft and weapons systems. A dual-use technology spin-off has also been developed with a Youngstown State University Industry Consortia of Metal Foundry Companies.



Improved Hybrid Ball Bearings Offer Increased Service Life

Payoff

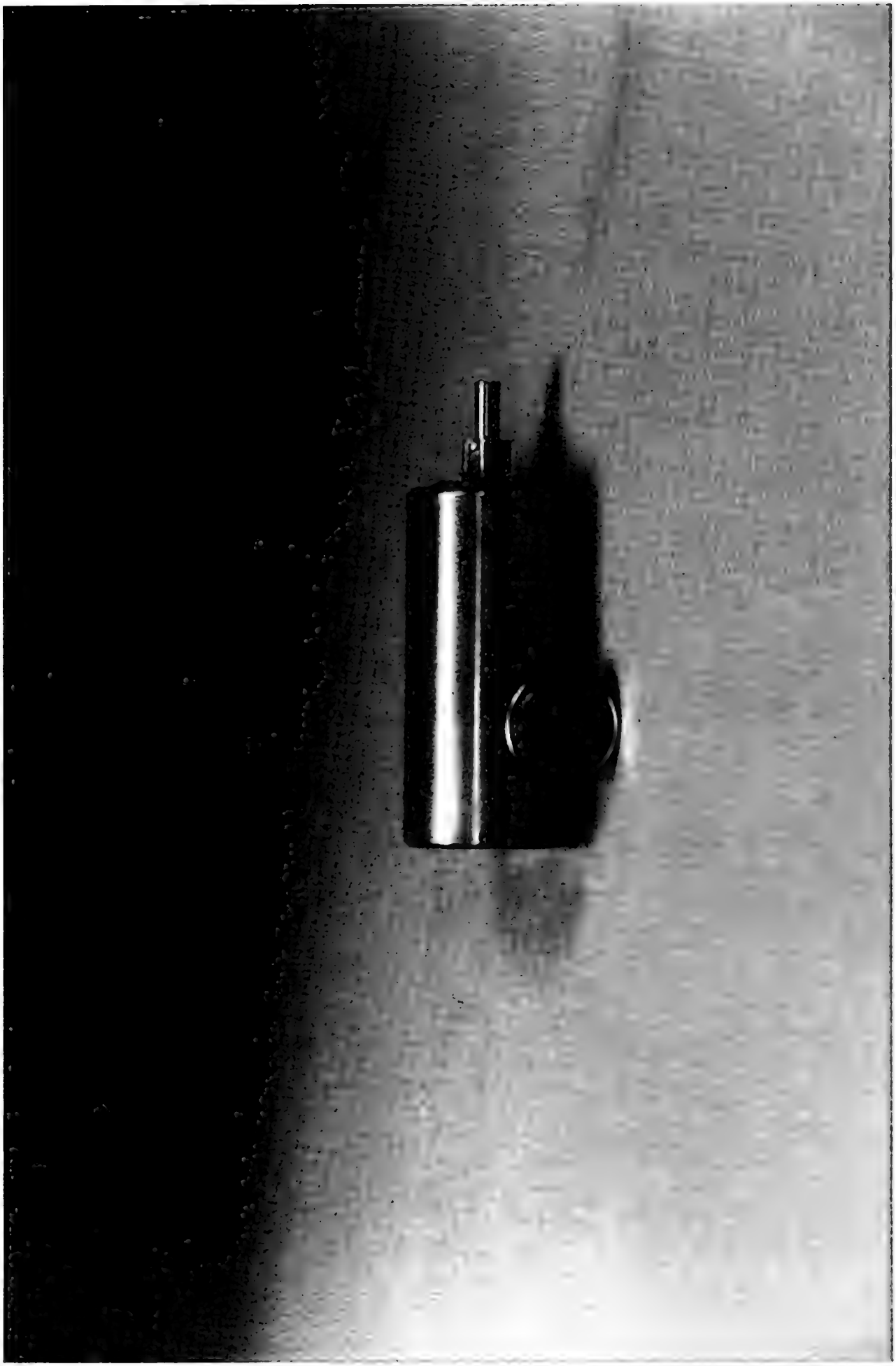
Nitriding (a hardening process) the steel raceway surface of a hybrid ball bearing will benefit bearing applications where resistance to contamination and debris is needed, and where thin fluid or solid lubrication films could result in damage to the raceway surfaces. The reduced lubrication requirement of the improved hybrid bearings as well as longer life cycle, combine to make them well-suited for Air Force systems where service requirements demand extended bearing life.

Accomplishment

Researchers at Wright Laboratory's Materials Directorate and The Torrington Company of Torrington CT developed an advanced process that produces a nitrided zone on the raceway surfaces of ball bearings that is an integral part of the steel surface and cannot break or spall off. The resulting hybrid ball bearings have a service life that is eight times longer than that of earlier hybrid bearings and twenty times longer than all-steel bearings in heavy-duty applications.

Background

Ball bearings are critical components in machinery with rotating parts. In the Air Force, the performance of equipment with ball bearings often determines the degree of success with which a weapon system completes its mission. In addition, as service life of Air Force systems are extended, they often require bearings with extended performance capabilities. For years, ball bearings have been made with steel balls and steel races. Severe operating conditions could cause the races to break, spall and pit, leading to early failure. As performance requirements increased, hybrid bearings were developed with silicon nitride ceramic balls. These bearings produced a 10-fold service life improvement over all-steel bearings, even though the mechanical properties of the steel races were not up to those of the ceramic balls. To complement the properties of the silicon nitride balls, the process for nitriding raceway surfaces of bearings produces raceway surfaces in the same hardness range as the ceramic balls. The nitrided zone of the raceway is an integral part of the steel surface and cannot break or spall off. A very high residual compressive stress zone near the raceway surface provides additional resistance to rolling contact fatigue in hybrid bearings. Improved corrosion resistance from the nitriding can extend the useful life of hybrid bearings in many applications. These hybrid bearings (offered commercially by The Torrington Company) could be used on the spindles of precision machine tools and grinding machines and as heavy-duty thrust bearings.



THERMOCHEMICALLY ACTUATED MOTION (TCAM) VALVE ACTUATOR TECHNOLOGY DEMONSTRATED

Payoff

A TCAM valve actuator is a low cost, lightweight, highly reliable alternative to electrohydraulic control valves. This technology could benefit future aircraft control and generate many advances in state of the art improvement in actuator characteristics, particularly, in the area of small instrument and control actuators and hydraulic cylinder replacements. There is commercial interest in this technology from the medical, manufacturing, automobile and entertainment fields.

Accomplishment

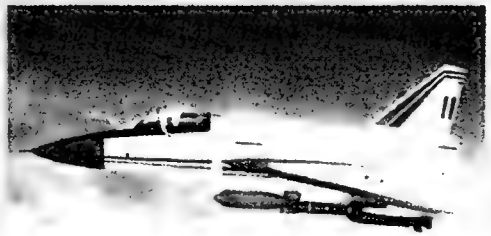
Under a Small Business Innovation Research (SBIR) program sponsored by the Fight Dynamics Directorate's Flight Control Division, the feasibility of applying new thermally expanding polymer actuation technology to aircraft valve control was demonstrated. This new mechanical actuation process is based on thermally expanding polymers in a self-contained hydraulic cylinder which does not require support equipment such as pumps, reservoirs, valves, etc. Current TCAM actuators are capable of 170 millisecond operation with very large volumetric expansion exceeding 30,000 psi.

Background

The state of the art in proportional hydraulic control currently requires complex hydraulic amplification circuits to amplify low power control signals to a level capable of operating the large electrohydraulic valves that control hydraulic actuators operating flight control surfaces. These valves provide power conversion and precise control of the mechanical advantage necessary to transform low power electrical signals into high force mechanical motion. They contain many precision machined parts that result in an undesirable level of failure modes and maintenance requirements. The Flight Dynamics Directorate initiated the SBIR program with TCAM Technologies, Inc. to evaluate the feasibility of their valve control technology to operate final valve assemblies directly, thereby reducing the complexity of the circuit's hydraulic portions. The TCAM process is accomplished using the large volumetric expansion of polymers in the melt zone. Polymers are inserted into pressure vessels outfitted with a piston arrangement, and a means of heating and cooling is provided to cycle the polymer through either a melting point or a glass transition temperature. In essence, the device is the equivalent of a hydraulic cylinder without the entire hydraulic support system.

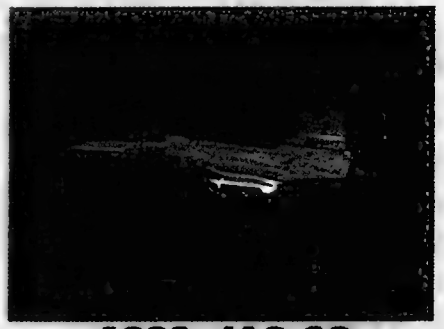
NT-33A IN-FLIGHT SIMULATIONS

1960 X-15



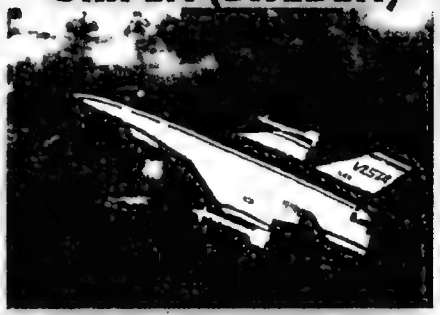
1995 LIGHT COMBAT AIRCRAFT (INDIA)

1990 YF-22

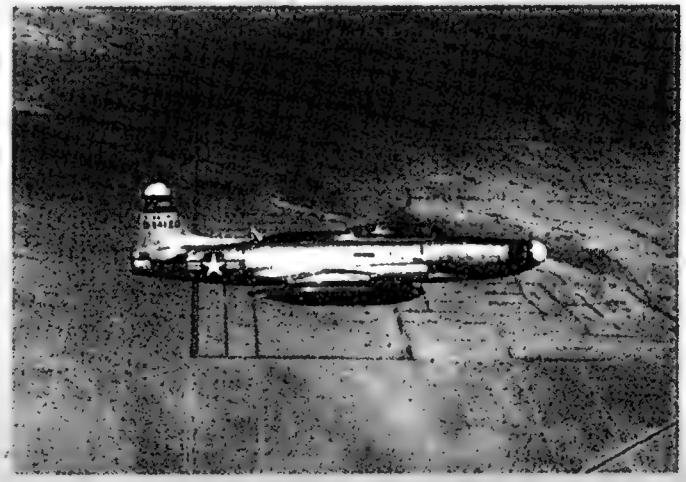


1989 JAS-39 GRIPEN (SWEDEN)

1971 A-10



1987 VISTA/NF-16D



1957-PRESENT

1972 F-15

1985 LAVI (ISRAEL)

1972 YF-17

1973 F-16

1978 F-18

1981 AFTI/F-16

40TH ANNIVERSARY OF THE NT-33A IN-FLIGHT SIMULATOR

Payoff

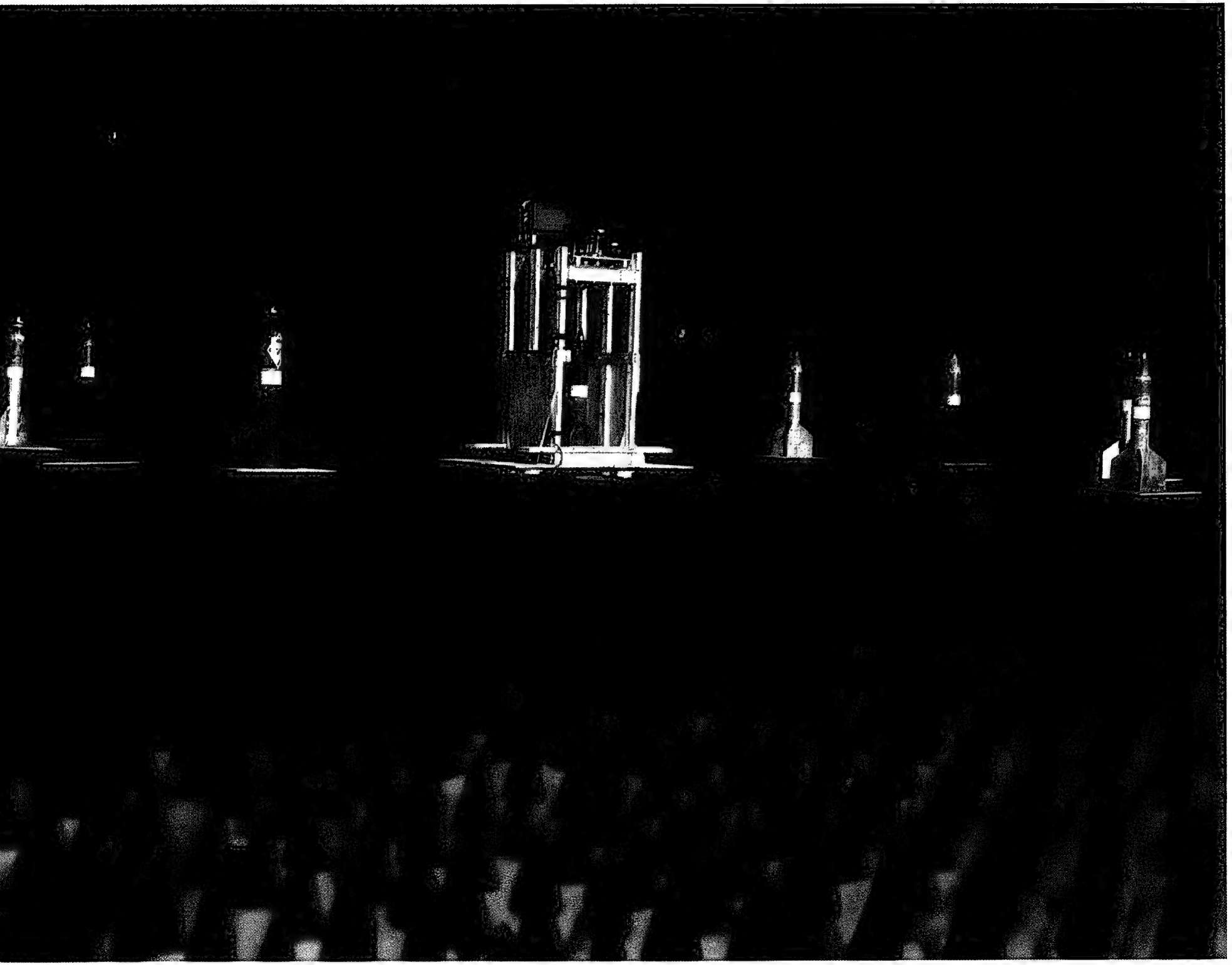
The NT-33A has aided the Department of Defense research and development mission by providing a highly useful and cost effective tool to researchers and aircraft designers. In-flight simulation allows an early evaluation of flying qualities in a realistic environment, provides a flexible platform for many types of research and enhances the training of new test pilots. These translate into greater confidence in new designs, decreased risk on the first flight of new aircraft and better qualified test pilots.

Accomplishment

The NT-33A in-flight simulator completed forty years as one of the world's truly unique and versatile research aircraft. This unique research aircraft has been used to predict flight characteristics of new aircraft that have not yet flown, correct flight control deficiencies and to perform generic research in the areas of flying qualities, flight control design, cockpit displays and human factors. The aircraft has also been used to train new test pilots. The NT-33A is the oldest flying Air Force aircraft and is the longest continuously operated research aircraft in the Air Force. Its successes are the result of the combined efforts of the Flight Dynamics Directorate and Calspan Advanced Technology Center (formally Cornell Aeronautical Laboratory), Buffalo NY.

Background

The Air Force accepted the T-33A in October 1951 and used it initially for engine research. The Air Force then assigned it to the Flight Control Laboratory, predecessor for the Flight Dynamics Directorate, and delivered it to the Cornell Aeronautical Laboratory in October 1954. Cornell modified the T-33A into an in-flight simulator and the aircraft made its first flight as the NT-33A in February 1957. Major modifications included: replacing the original nose with a larger one to house additional electronic systems; relocating internal systems and installing a data recorder, sensors, and computers upon which desired flight characteristics could be programmed; installing an independently controlled hydraulic center stick whose input went to the computer and installing hydraulic actuators controlled by the computer on all primary control surfaces. The first research program was performed in December 1959 and investigated the flying qualities of lifting bodies. The NT-33A has been active ever since, having supported the development of aircraft such as the X-15, A-10, F-15, F-16, YF-17, F-18, F-22, Lavi (Israel), and JAS-39 Gripen (Sweden). It has also performed research in the areas of flying qualities, flight control design, human factors and head-up displays. The NT-33A is also used by the Air Force and Navy test pilot schools to train new test pilots in issues pertinent to digital flight control design and display requirements. Most of the aircraft's electronic systems have been upgraded over the years, and other additions include a digital flight control system, fully programmable side stick and a head-up display.



Proximity Sensor Tested For General Purpose Bombs

Payoff

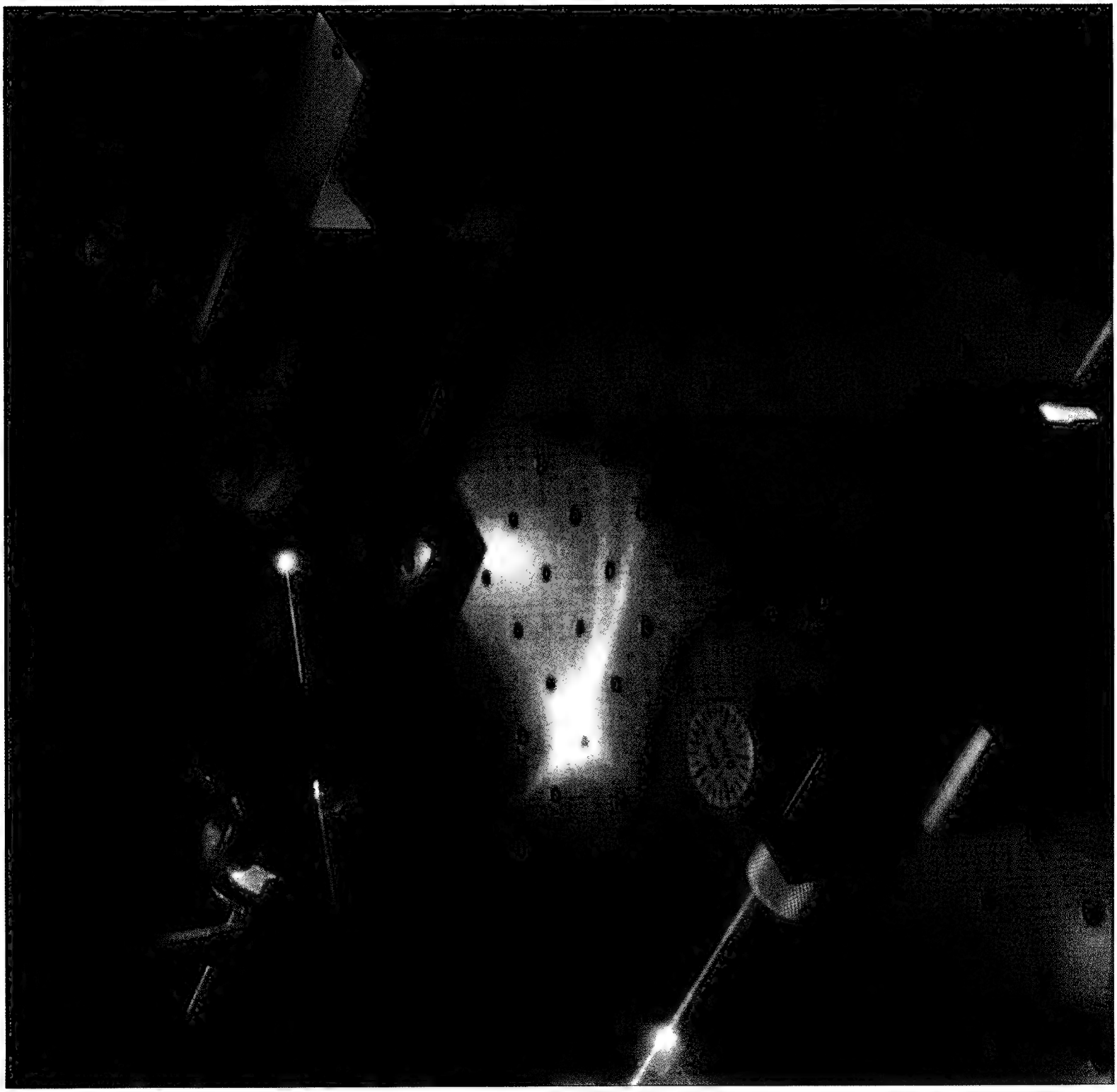
The successful array tests in an anechoic chamber of the Army's multi-option fuze for artillery (MOFA) proximity sensors enabled the Air Force to move one step closer to a one piece fuze stored in the warhead (All-Up Round Fuze) for general purpose bombs. The Air Force will realize an improvement in aircrew safety and in the number of bombs detonating on or near the target.

Accomplishment

Personnel from Wright Laboratory's Armament Directorate, the Air Force Development Test Center and the Army Armament Research, Development and Engineering Center (ARDEC) teamed to successfully test a miniature proximity sensor for use in aerial bombing. Utilizing a large anechoic chamber located at Eglin Air Force Base for the test, the team determined that an off-the-shelf Army fuze proximity sensor can meet Air Force mutual interference criteria for multiple bomb drops.

Background

The All-Up Round Fuze program goal is to affordably combine the Army's proximity sensor, a wind turbine generator and an in-line explosive train, capable of detonating insensitive high explosives, into a one piece fuze stored in the warhead. The MOFA proximity sensor, identified through Project Reliance, uses a microwave monolithic integrated circuit (MMIC), frequency modulated continuous wave radar of very low power and a sophisticated signal processor. It was developed by ARDEC to meet low cost artillery needs. The mutual interference criterion originates from the ripple or salvo drop of general purpose bombs where bomb-to-bomb distances during free-fall can be as close as five feet in a 24 bomb pattern causing some weapons with proximity fuzes to detonate prior to reaching the target. The test included a telemetry-equipped fuze at the center of a 31 point, close packed hexagonal pattern. Seven other fuzes were located at various points on the pattern with their antennae lobes oriented so as to maximize mutual interference. The center fuze was co-located with a device which simulated the effect of the sensors flying into the ground with various ground reflectivities. No significant self-jamming occurred until the fuzes were brought to within three feet of each other exceeding the Air Force's requirement.



The New Laser-Based Sensor Provides Real-Time Control Of High-Temperature Coating Process

Payoff

The new laser-based sensor offers precision control over coating applications that are essential for prolonging the life of critical components in Air Force turbine engines. Besides coatings for precise, high-temperature barrier applications, the laser ultrasonic sensor can be used to measure ceramic and polymeric coatings on the skins of advanced Air Force aircraft. It can also be used as an end-process sensor to measure the thickness of virtually any kind of coating.

Accomplishment

Researchers at Wright Laboratory's Materials Directorate, working with scientists at United Technologies Research Center at East Hartford CT, have found a way to make noncontact, nondestructive, on-line measurements of the thickness of high-temperature coatings. Their method, which improves the quality and consistency of coatings, employs laser ultrasonics to accurately measure the thickness of coatings which are as thin as two mils, at temperatures as high as 1400° Celsius.

Background

Many parts for advanced Air Force systems must meet stringent requirements for light-weight, resistance to high-temperatures, consistent performance and long operational life. Coatings have become critical elements in meeting these requirements by providing vital protection for precision components which must operate in extreme environments. One such coating material, crystalline silicon nitride, is being applied as a thermal resistance barrier for carbon-carbon rotors in advanced, high-temperature turbine engines under the Integrated High-Performance Turbine Engine Technology initiative. Because the rotors must operate at high-speeds, precision balance is critical. Coating thickness must be uniform over all surfaces of the rotor, including each blade. Currently, measuring the thickness of coatings applied at high-temperatures is done by estimation, or by destroying a part for after-the-fact measurements. Because measurements with the newly developed laser ultrasonic sensor system are made in real-time, even at temperatures as high as 1400° Celsius, coating thickness can be accurately monitored and controlled. In operation, a pulsed laser ultrasonic generator directs a ring-shaped pulse at the coated surface. Ultrasonic waves travel through the coating to a central laser sensor point and are picked up and reflected back to an interferometer sensor so the coating thickness can be detected and read out directly. On-line, real-time measuring offers precision control over the coating process, especially when the interferometer sensor is linked to the coating equipment. Nondestructive operation permits measurements to be made even during the application of coatings.

New Production Process For Complex Semiconductors Permits Reduced System Size, Improved Performance

Payoff

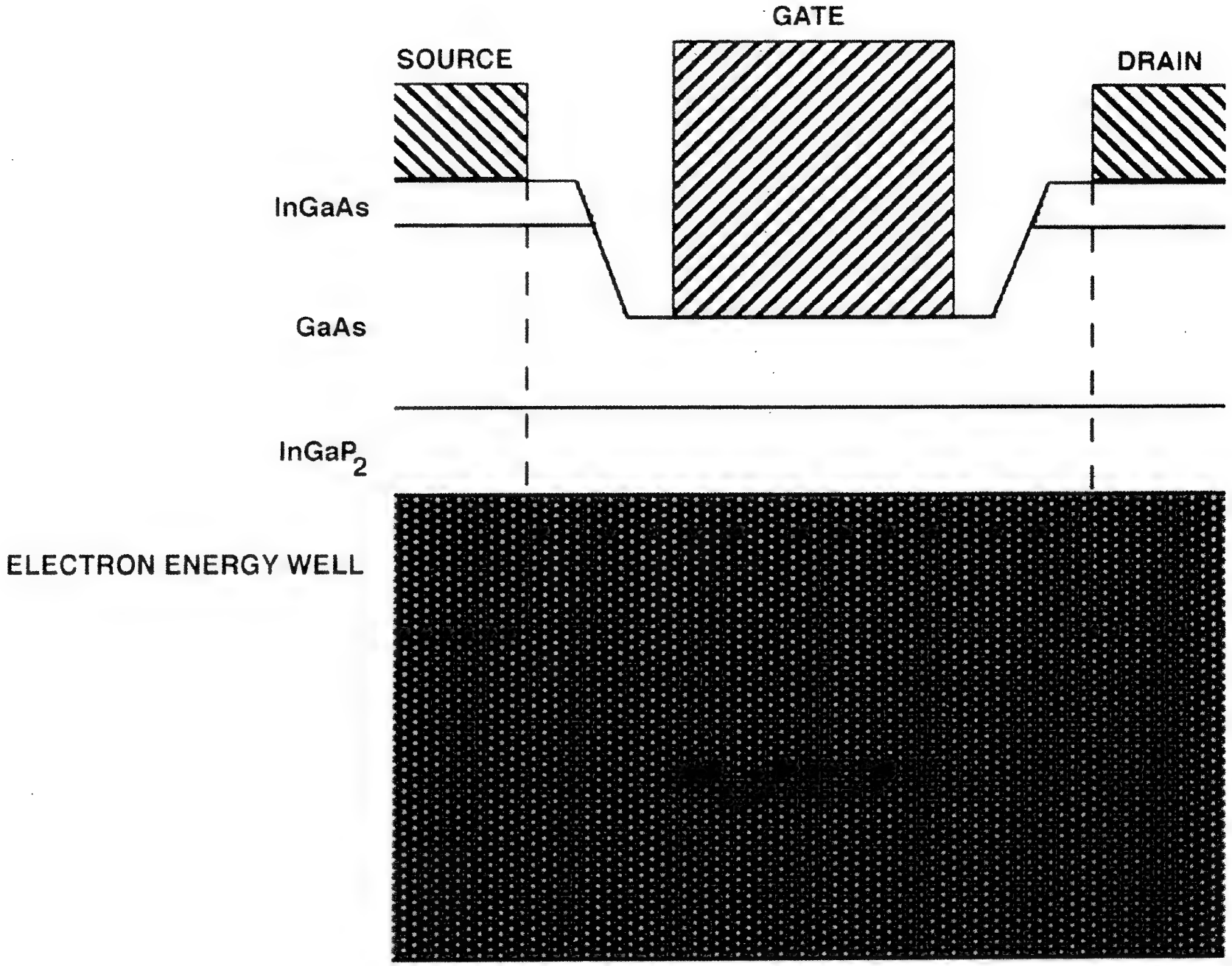
A multiple function semiconductor chip (shown left, foreground) replaces complete circuit boards (shown left, background) in advanced electronic systems while generating a higher-powered output and less heat. With the new production process, these complex chips can be used to combine Air Force systems such as infrared detection and signal processing or radar transmit and receive systems onto single chips. The new process offers 70 percent savings in production time and 50 percent savings in processing cost.

Accomplishment

Researchers at Wright Laboratory's Materials Directorate, working with scientists at the University of California-San Diego, developed a new production process which employs lasers for selective deposition of dissimilar materials onto a wafer to combine several semiconductors onto a single chip. This process can permit electronic system size reduction by as much as 60 percent.

Background

Semiconductors, the basis for all solid state electronic systems, have permitted the miniaturization of scores of Air Force electronic systems. Semiconductor production has traditionally been done by patterning, masking and etching -- a low-yield, high-cost process. Advanced Air Force electronic systems demand greater accuracy for higher performance. At the same time, these higher-powered systems must often be downsized to increase payload or operational range of aircraft. One method to help achieve these requirements is to combine several semiconductors using the direct-write selective area epitaxy process, even those with different materials, onto a single chip. For example, transmit and receive systems for airborne radar can be combined into a single chip, as can infrared detection and signal processing systems, as well as complete controls for phased-array radar systems. Other uses for multiple function semiconductor chips might include combining electro-optics with digital electronics for greater capacity, and savings in weight and space.


GATE
SOURCE
DRAIN
InGaAs
GaAs
InGaP2
ELECTRON ENERGY WELL

New Production Process Improves Power Density, Reduces Size Of Complex Semiconductors

Payoff

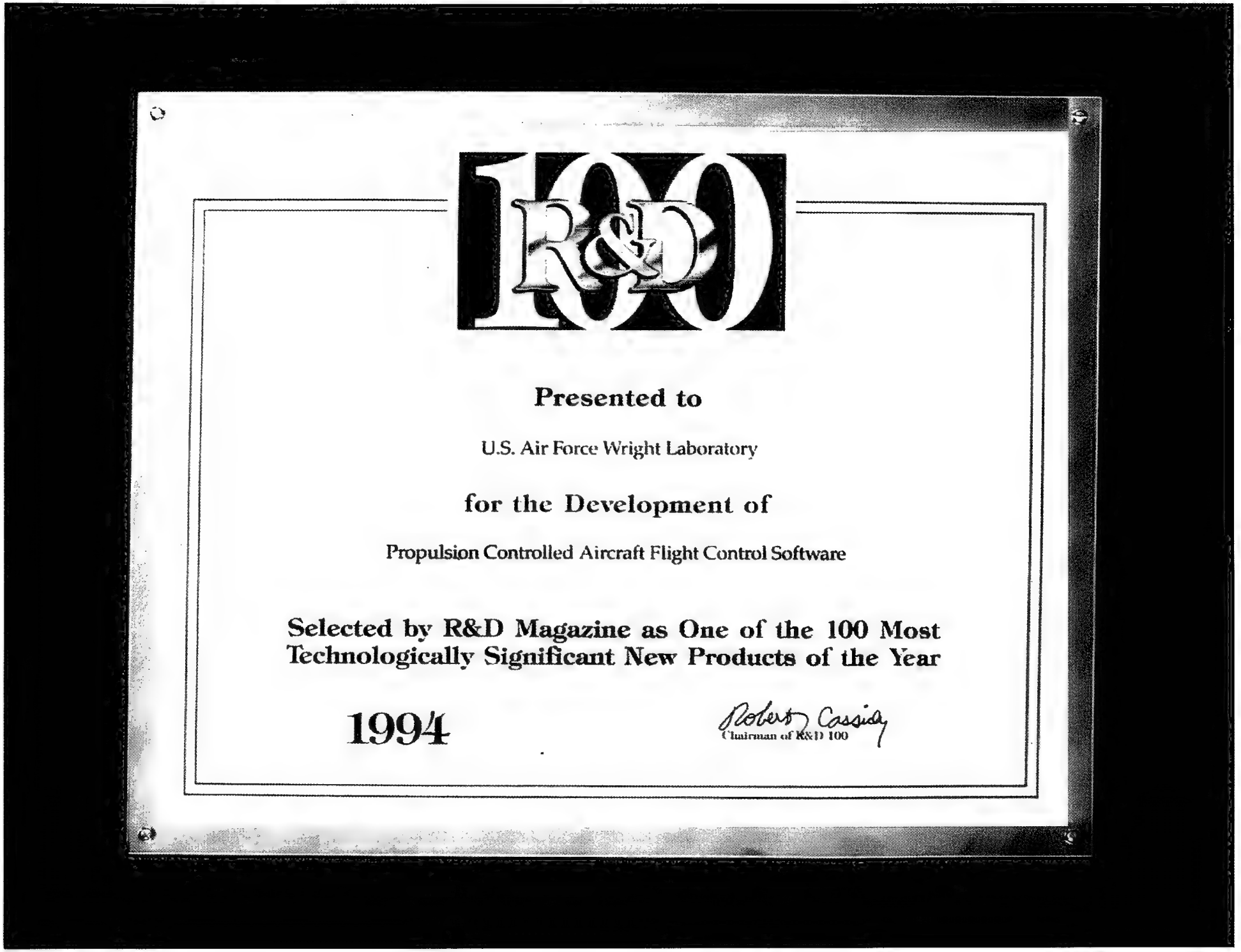
Development of a fast, highly accurate production metal-organic molecular beam epitaxy (MOMBE) process makes it possible to prepare complex semiconductors (structure of a typical semiconductor shown left) that can be downsized by as much as 90 percent while offering three times the power density. Savings in size and weight make it possible for semiconductors produced by this process to be used in advanced space-based radar and communication systems that operate in the millimeter and sub-millimeter ranges.

Accomplishment

Wright Laboratory's Materials Directorate, working jointly with American Telephone and Telegraph Bell Laboratories, Murray Hill NJ and General Electric/Martin Lockheed, Syracuse NY, developed a new production process for complex semiconductors. High-speed, digital integrated circuits produced by their MOMBE process have shown over a 50 percent reduction in defects for a corresponding increase in yield.

Background

For many years, most multiple-layer semiconductors have been prepared by metal-organic chemical vapor deposition (MOCVD), a process not accurate enough for devices requiring high power density. Another process, molecular beam epitaxy (MBE), offers high accuracy, but is too slow for most production requirements. Neither process appears able to meet future requirements for quality and cost efficiency in the production of complex semiconductors. MOMBE combines the best advantages of the MOCVD and MBE processes with few of the drawbacks. Semiconductors produced using the MOMBE process can provide increased resolution in millimeter wavelength radar systems to enable helicopter pilots to see and avoid power lines while conducting night operations.


R&D
Presented to
U.S. Air Force Wright Laboratory
for the Development of
Propulsion Controlled Aircraft Flight Control Software
Selected by R&D Magazine as One of the 100 Most Technologically Significant New Products of the Year
1994
Robert Cassidy
Chairman of R&D 100

PROPULSION CONTROLLED AIRCRAFT TECHNOLOGY SELECTED FOR 1994 R&D 100 AWARD

Payoff

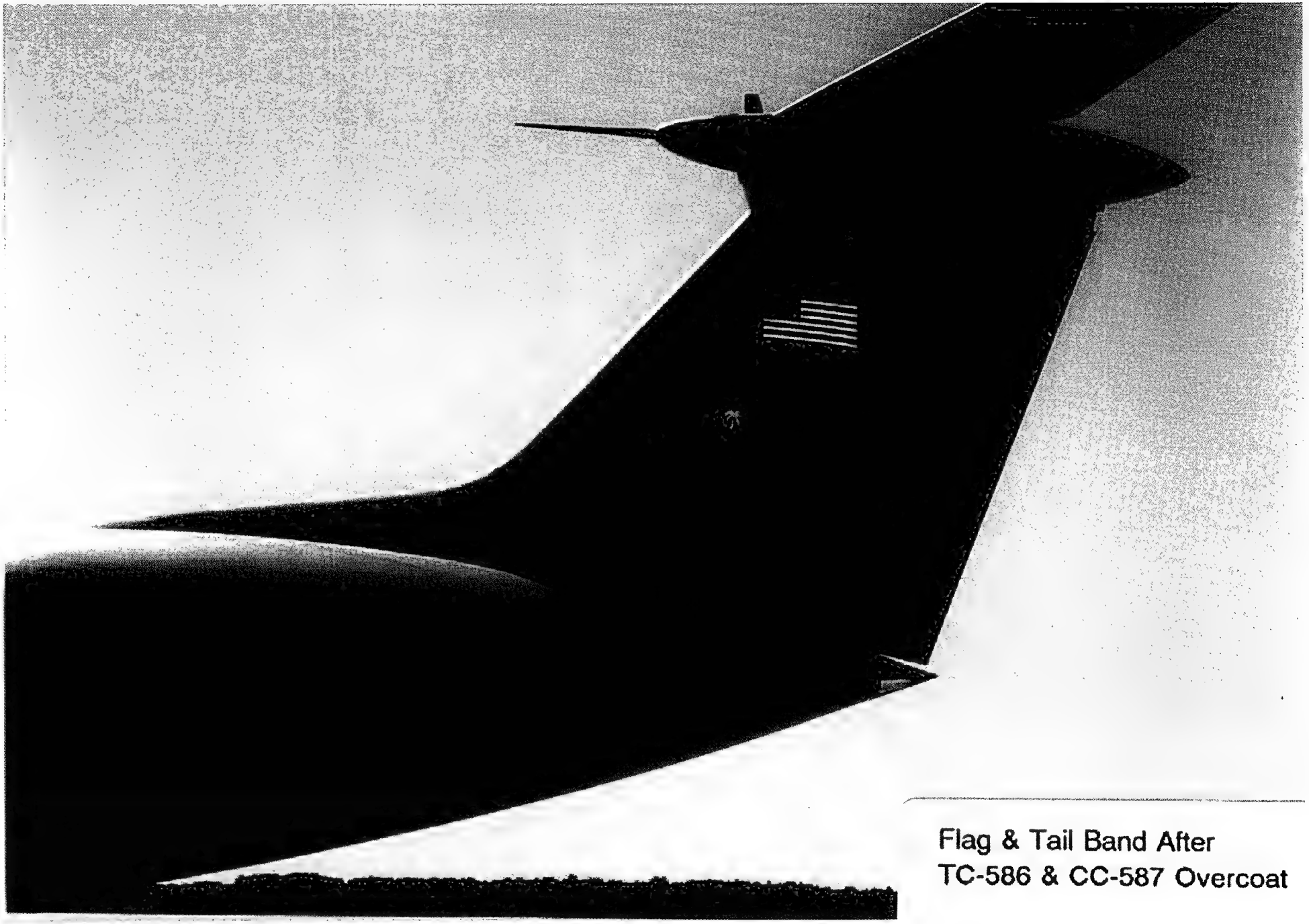
R&D Magazine identified the Propulsion Controlled Aircraft (PCA) Flight Control Software as one of the 100 most technologically significant technologies of the year. This technology, coupled with other current digital and sensor technologies, offers the potential to recover damaged or impaired military and civilian aircraft without the loss of life.

Accomplishment

The development of PCA Flight Control Software was recognized by R&D Magazine as one of the 100 most technologically significant products of 1993. The award given to Wright Laboratory was one of the prestigious R&D 100 Awards made in 1994. This PCA program, partially funded by Wright Laboratory and managed by NASA Dryden, used software developed by McDonnell Douglas. This computer program automated thrust augmentation functions to assist the pilot in successfully landing an impaired (all of its flight control surfaces locked) F-15 aircraft at Edwards AFB CA using thrust only (no thrust vectoring) for control.

Background

Each year R&D Magazine recognizes the 100 most technologically significant new products of the year. Called the "Oscars of Invention" and the "Nobel Prize of Applied Research," one of the 100 awards presented in September 1994 went to the Propulsion Controlled Aircraft Flight Control Software team members. They were recognized for their successful development and demonstration of an alternative approach to help pilots fly severely damaged aircraft to a safe landing. An extension of the joint Air Force/NASA Self-Repairing Flight Control System program, the PCA program received its impetus following the 19 July 1989 crash of a United Airlines DC-10 due to complete flight control surface lock. Preliminary attempts to control the aircraft through manual control of the throttle only, even when level and trimmed out, was determined to be very difficult but possible. The PCA team found that, lacking the precision required to land the aircraft due to a lightly damped Dutch roll, Phugoid mode oscillation and slow response of the engines to throttle changes, automatic thrust augmentation was required. A computer program, using normal aircraft sensors and displays, measures aircraft angle and rate information and couples it with pilot commands to provide the augmentation required to safely land the F-15 with its flight controls locked. The display shows the commanded flight path of the aircraft enabling the pilot to immediately know the effect of his commands, thereby precluding over or under control of the aircraft. This system allowed consistently safe landings in a piloted simulator leading to the actual safe landing of the F-15 in April 1993. Transition of this technology to transport and commercial aircraft is underway.



Flag & Tail Band After
TC-586 & CC-587 Overcoat

Low Infrared Coating Program Provides Interim And Long-Term Solutions

Payoff

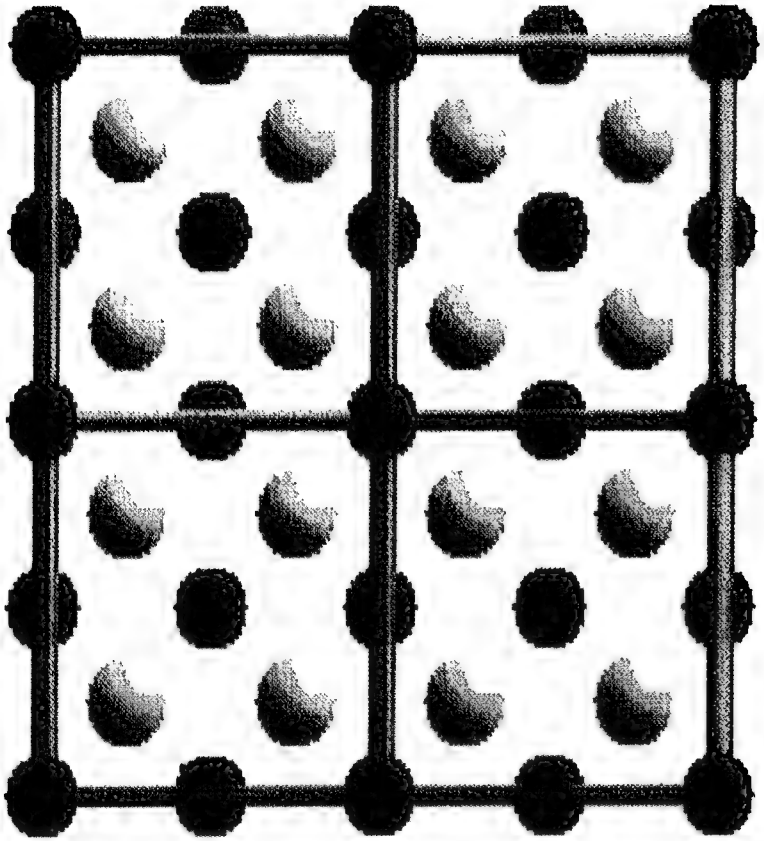
The low infrared coatings program provided a fast interim solution, as well as a proven, highly effective long-term solution for reducing solar effects on Air Force aircraft. Off-the-shelf coatings identified through the program will make Air Mobility Command (AMC) aircraft less vulnerable to infrared tracking systems.

Accomplishment

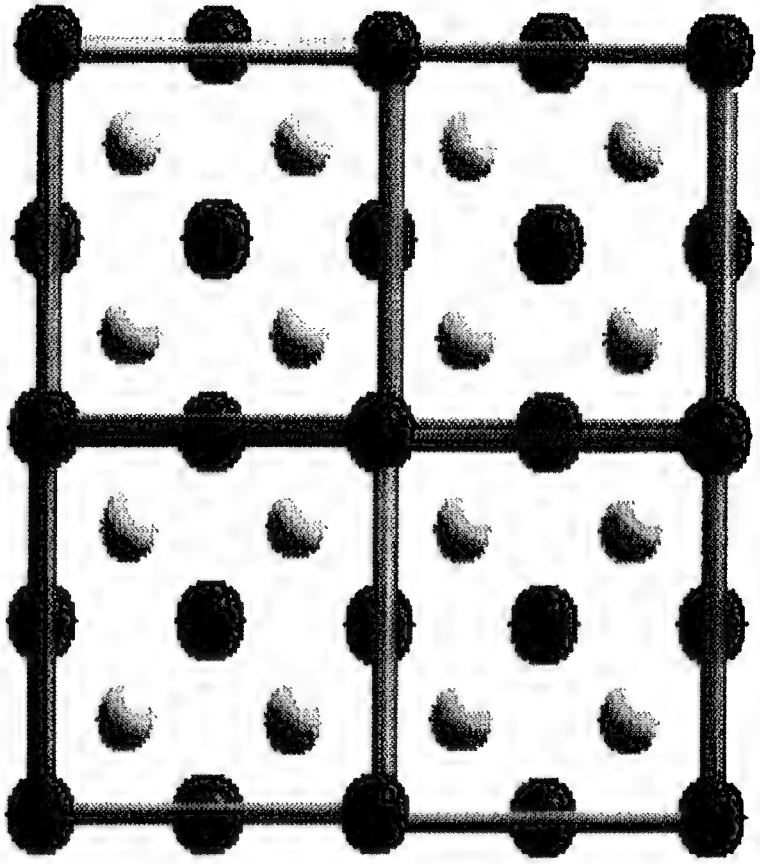
Research by engineers and scientists from Wright Laboratory's Materials, Avionics and Plans Directorates led to the identification of low infrared coatings for AMC aircraft that minimize solar effects on an aircraft's vulnerability to infrared threats. Both a short-term solution and a long-term solution met the minimum durability requirement of 50 flight hours.

Background

AMC aircrews often fly into hostile areas of the world to deliver personnel, supplies and equipment. In these environments, infrared-seeking missiles threaten aircrews and mission accomplishment. To make AMC's transport and tanker aircraft less vulnerable to infrared tracking systems, AMC officials asked the Materials Directorate to identify a coating to reduce solar contributions to aircraft vulnerability. Within a month, engineers from the Directorate's Nonmetallic Materials Division and Systems Support Division provided AMC with a short-term solution. They identified a suitable coating that met the minimum durability requirements of 50 flight hours. In developing a long-term solution, candidate coatings were tested for effectiveness and durability. An array of Materials Directorate equipment and facilities were used to test various coatings for adhesion and resistance to rain erosion, ultraviolet exposure, high-temperatures, humidity and a range of operating fluids, as well as optical properties. Throughout, close cooperation with suppliers paid off in quick response times to provide off-the-shelf coatings and near-off-the-shelf revised coatings. Testing was conducted against infrared sensors in flight tests at Eglin AFB and Wright-Patterson AFB. Engineers in the Avionics Directorate, and the Signature Technology Office of the Plans Directorate handled sensor analysis. The final coating selection met requirements for application using standard Air Force techniques as well as minimum durability requirements for application of 50 flight hours. For his leadership in moving this program to completion in less than 12 months the project manager, George F. Schmitt, Jr., of the Materials Directorate's Nonmetallic Materials Division, earned the Meritorious Civilian Service Award.



DISORDERED DIAMOND TERNARY



ORDERED DIAMOND TERNARY

Advanced Semiconductor Material Can Improve Performance Of Near-Infrared Solid State Lasers

Payoff

Highly ordered indium gallium phosphide In (GaP_2) crystal layers, integrated on a gallium arsenide substrate to form arsenide lasers, can improve the performance and reliability of tunable mid-infrared laser systems for military, industrial and medical applications. This advanced material can also improve communication networks and aircraft warfare countermeasure systems, and make possible remote pollution monitoring systems.

Accomplishment

Under a Small Business Innovation Research program sponsored by the Wright Laboratory's Materials Directorate, Spire Corporation of Burlington, MA developed an advanced non-linear optical crystal semiconductor material that improves the performance of near-infrared solid state lasers. The material, $InGaP_2$, is specially constructed for maximum useful nonlinearity and clarity, and eliminates many of the shortcomings associated with conventional materials.

Background

Lasers today are at work in an incredibly broad range of applications, from laser guided bombs for the military to laser surgery for the medical field and industrial lasers for machining operations. One widely used near-infrared laser is based on gallium arsenide crystals. These gallium arsenide lasers use components which have been constructed from layers of aluminum gallium arsenide, a material that has proven susceptible to oxidation, causing reduced life performance and early failure. Specially constructed $InGaP_2$ layers have proven to be a promising new material to replace aluminum gallium arsenide layers in gallium arsenide lasers. This atomically ordered $InGaP_2$ has outstanding crystal uniformity and low absorption loss. It bonds well with the gallium arsenide substrate because it matches the substrate perfectly and the oxidation resistance of $InGaP_2$ is superior due to the elimination of aluminum as a component. Highly ordered $InGaP_2$ layers integrated on a gallium arsenide substrate will produce improved gallium arsenide lasers which can be used as solid state optical pumping sources in high-efficiency, compact, tunable mid-infrared lasers for Air Force optical countermeasure systems. Other potential Air Force applications include more efficient solar cells and improved optical detectors. Commercially, gallium arsenide lasers incorporating $InGaP_2$ will be useful in medical applications such as photodynamic therapy which involves the use of photosensitive dyes in the treatment of a number of skin ailments.

Award For Contributions To Ceramic Matrix Composites Development

Payoff

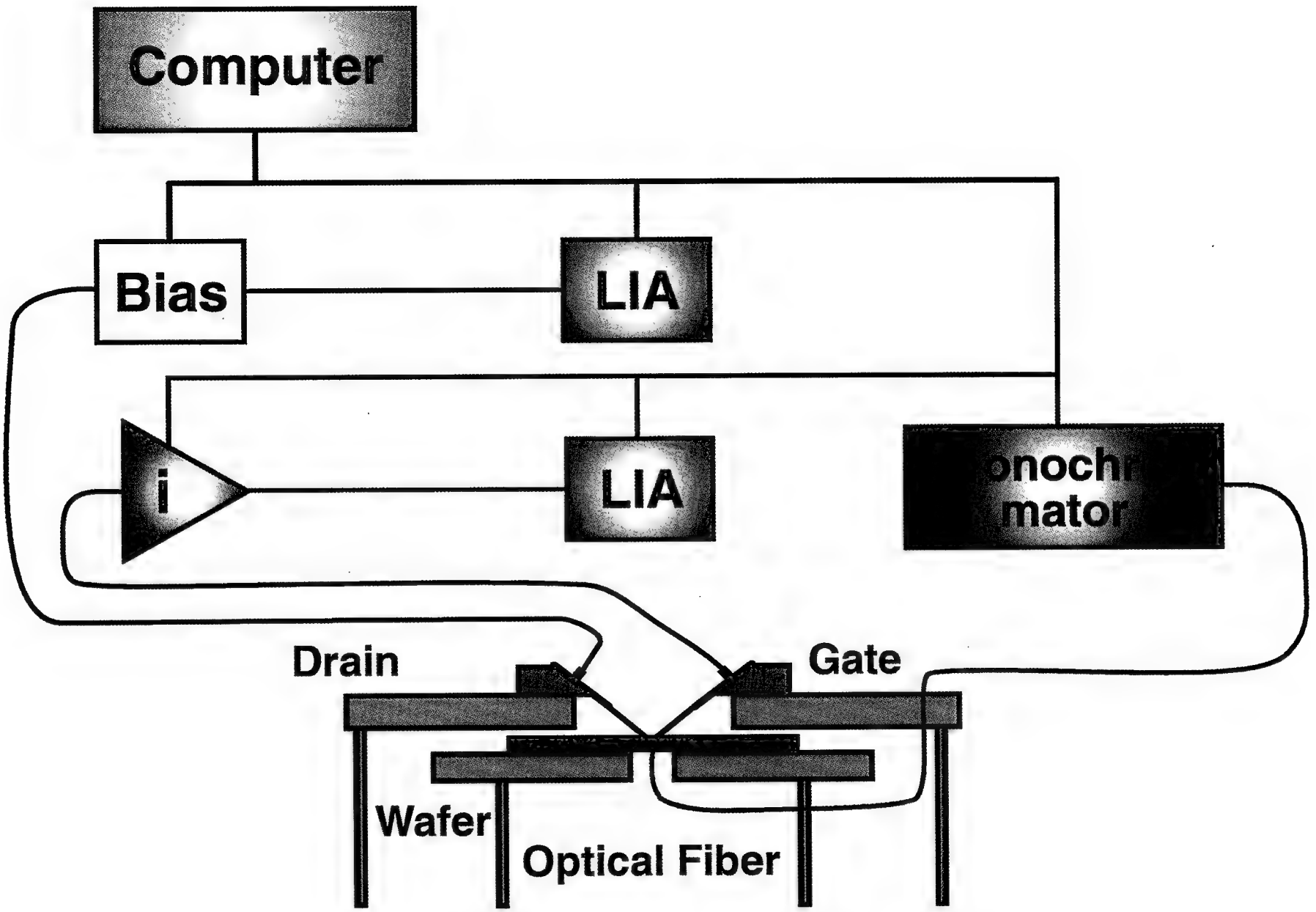
Dr. Ronald J. Kerans' role in the development of ceramic matrix composites has led to the transition of these materials to Air Force systems such as the advanced turbine engine. Dr. Kerans' contributions to the development of advanced fiber-matrix interface concepts will result in the transfer of these concepts to industry to meet a range of military and commercial needs. He is a role model in showcasing Wright Laboratory's research and development accomplishments.

Accomplishment

Dr. Ronald J. Kerans of Wright Laboratory's Materials Directorate received the 1995 Engineering and Science Award from the Engineering and Science Foundation/Affiliate Societies Council of Dayton for his lifetime leadership and contributions to the design and development of ceramic matrix composite materials. As an international leader and authority in the ceramic composite community, Dr. Kerans led research on composite interfaces that has resulted in the development of advanced fiber-matrix interface concepts.

Background

The Engineering and Science Foundation and Affiliate Societies Council of Dayton jointly sponsor annual Engineering and Science Awards presented to outstanding engineers and scientists in the Dayton area for significant contributions to their professions and the local community. One effort, led by Dr. Kerans, included an analytical model unique in its abilities. This model is the first to include interface roughness and all residual stresses and predict that these factors substantially affect ceramic matrix composite behavior. It is also the first model to clearly identify and isolate the most relevant interface property, the fracture toughness of the interface, from frictional and residual stress effects. These results have provided guidance for the design and development of a series of advanced fiber-matrix interface concepts. Newly initiated collaborations with industry will transfer these concepts to meet a range of military and commercial needs for improved state-of-the-art ceramic matrix composites and next generation materials. Dr. Kerans also led an activity that successfully identified a series of complex oxides capable of operating in advanced gas turbine engines at temperatures in excess of 3,000°F. This research resulted in the identification of a series of complex oxide materials, currently the focus of continued development in both Air Force and National Aeronautics and Space Administration programs for turbine engine applications.


Computer
Bias
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Drain
Gate
Wafer
Optical Fiber

New Photo-Electric Analysis Technique Of Pseudomorphic Transistors

Payoff

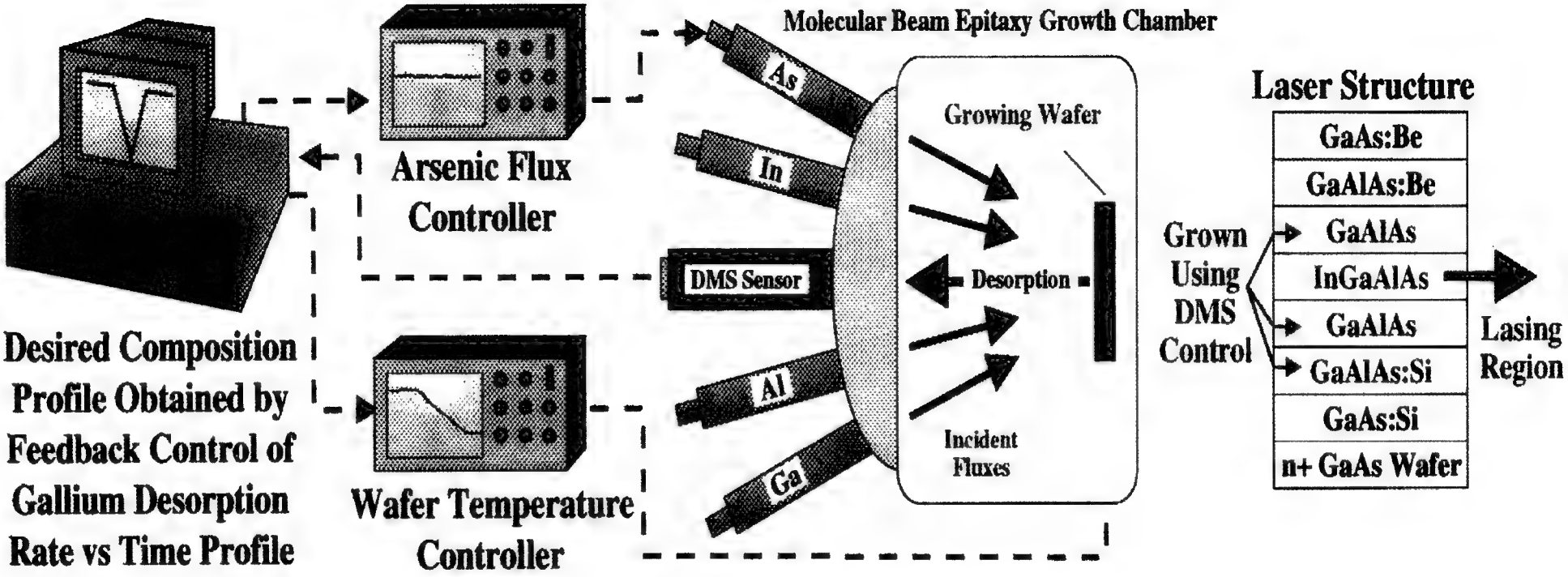
The photo-electric analysis of pseudomorphic (irregular form) high electron mobility transistors (PHEMTs), using the experimental set-up shown left, has revealed new insight into their operation. This technique has led to a better understanding of PHEMT characteristics and will help in optimizing the design of electronic devices for next generation avionics systems that will enable the Air Force to penetrate enemy territory with minimal danger to the aircraft.

Accomplishment

Wright Laboratory's Solid State Electronics Directorate invented a new technique based on photo-electric conduction and emission which allows nondestructive, on-wafer analysis of fully fabricated PHEMTs. This represents an important advancement in analysis techniques since device processing changes electronic materials parameters.

Background

PHEMTs are finding application in micro-electronic integrated circuits for use in electronic systems where superior performance is of paramount importance. Superior electronic technology has made it possible for the Air Force to penetrate enemy territory to perform surgical strikes with minimal danger to the aircraft. To retain this capability, it is necessary to continually improve the performance of the electronic systems. Pseudomorphic heterostructure device technology provides the foundation for next generation avionics systems. The pseudomorphic heterostructure transistors are formed in a materiel structure which is made up of many layers of different semiconducting and insulating materials. These layers are very thin with typical thickness of 50 to 100 atomic layers. Optical techniques have been used routinely to investigate these material structures. The new photo-electric analysis technique modifies the energy configuration within the thin layers by applying electric potentials to the drain and gate electrodes. In the experimental setup, monochromatic (single wavelength) light is directed towards the backside of the wafer via a fiber optic cable. The measurements are performed in a wavelength regime in which the substrate is optically transparent at the selected wavelength and the light can be absorbed in the channel of the device, resulting in photogeneration of electron-hole pairs. These charges are detected as photocurrents at the electrodes.



DMS Control of MBE for Advanced Semiconductor Laser Technology

In-Situ Control Of Crystal Growth Advances Semiconductor Laser Technology

Payoff

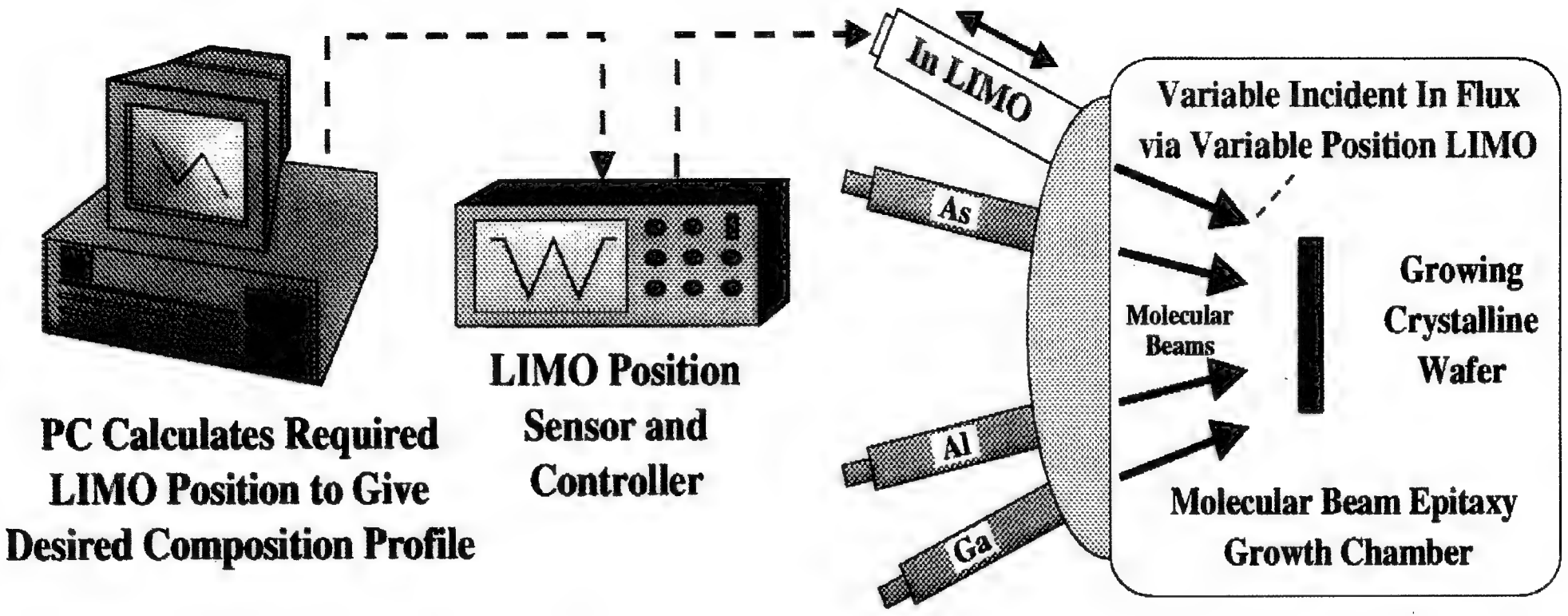
The ability to optimize optical and electrical properties while maintaining continuous control of the composition of the growing wafer makes the desorption mass spectrometry (DMS) feedback approach extremely attractive for semiconductor laser applications. The improved reproducibility of laser wavelength which should result from a Cooperative Research and Development Agreement (CRDA) is expected to provide significant cost reduction and yield enhancements associated with producing lasers designed to operate in specific narrow wavelength regions.

Accomplishment

A research development in the Solid State Electronics Directorate, which pioneered fundamental studies of molecular beam epitaxy (MBE) growth processes, has resulted in the initiation of a CRDA between the Directorate and Semiconductor Laser International (SLI) of Binghamton NY. The in-situ sensor technique called DMS has enabled the monitoring and controlling of growth conditions during MBE to produce ultra-thin layered semiconductor structures for advanced laser applications.

Background

The Solid State Electronics Directorate's Device Materials Branch received the 1992 Air Force Office of Scientific Research Star Award for excellence in basic research in the area of crystal growth science. Their continued success in pioneering fundamental studies of MBE growth processes has hinged on their development of the in-situ sensor technique called DMS. The DMS sensor, when placed in the MBE crystal growth environment, provides for continuous monitoring of several important growth parameters. When the Directorate's researchers implemented conventional feedback principles to control the DMS sensor output, an unprecedented ability to continuously control the composition of the growing film under conditions giving rise to significant desorption was provided. Such conditions are well known to benefit the optical and electrical properties of the resulting crystalline structure but are traditionally avoided because of the loss of control of composition.



Linear Motion Oven (LIMO) for Variable Incident Molecular Beam Flux

Linear Motion Oven (LIMO) Provides Critical Advances In Semiconductor Crystal Growth

Payoff

The advances in semiconductor crystal growth technology directly translate into enhanced yield, increased flexibility and reduced cost associated with production of semiconductor materials. These materials have direct application for advanced electronic and opto-electronic devices used both for military and commercial applications. As a result, EPI MBE, the largest United States - based manufacturer of molecular beam epitaxy (MBE) systems, formally applied for exclusive license of Wright Laboratory's advanced flux control technology.

Accomplishment

Researchers in the Solid State Electronics Directorate developed a LIMO that enabled three critical advances in the semiconductor crystal growth technology known as MBE. They discovered that imparting a linear movement capability to the traditionally stationary molecular beam source ovens, used in MBE chambers, greatly enhanced the reproducibility and flexibility associated with the MBE growth process.

Background

Many advanced electronic and opto-electronic devices are fabricated from semiconductor heterostructures produced by the MBE crystal growth process. The ability to reproduce device properties rests largely in the ability to control layer thicknesses and compositions during MBE crystal growth. While MBE is the most precise crystal growth process available, it also is very expensive - in part because of problems associated with flexibility and reproducibility. Movement of the LIMO during the MBE growth process results in vertical composition grading; i.e., the crystal composition varies in the growth direction. By computer-programming a time-varying LIMO position, purposely graded structures can now be produced simply and in a very reproducible manner, in marked contrast to previous approaches to obtain composition grading. Applications for such grading include: graded index regions in semiconductor laser diodes, graded contact regions in many devices, including field effect transistors, and graded emitter regions in heterojunction bipolar transistors. The ability to controllably and reproducibly grow structures for such applications directly improves the yield of the MBE growth process, which translates into reduced cost associated with advanced device production technology. The LIMO movement capability also enables two other important advances in MBE growth technology. Many devices require improvements in the uniformity of the incident molecular beams. Such uniformity improvement is a natural by-product of moving the LIMO back from the traditional oven position. Also, by keeping the LIMO in a "back" position when that oven is not in use, traditionally troublesome flux transients are completely eliminated.

New Fire Fighting Foam Contains Non-Toxic Chemical Component

Payoff

Testing demonstrated the aqueous film forming foam (AFFF) containing an environmentally friendly solvent blend performed equally as well as the AFFF containing a toxic solvent. By replacing the toxic chemical, butyl-carbitol, the requirement to report an AFFF spill over the reportable quantity limit, as required under the Emergency Planning and Community Right-to-Know Act (EPCRA), has been eliminated.

Accomplishment

Wright Laboratory's Air Base Systems Branch at Tyndall Air Force Base developed a non-toxic solvent blend that could replace butyl-carbitol (a glycol ether) in Military Specification foams without degrading the fire suppression properties of the foam. Since the blend is non-toxic, thus environmentally friendly, no severe restrictions would be placed on the use of the AFFF.

Background

Over the past several years, severe restrictions have been placed on the use of AFFF due to its disruption of waste water treatment plant operations, slow degradation in the environment and conversion of fuels into emulsions (as fat in milk). These restrictions include: limited training with AFFF; disconnecting AFFF hanger fire suppression systems from fire detectors and connecting them to heat detectors (which delays the time AFFF can be discharged in a fire event); and closure of over 100 fire training pits that previously used AFFF as a training agent. To develop a more environmentally friendly AFFF, the Air Force formed an AFFF Interagency Steering Group in 1993, which includes members from the Navy, Army and Federal Aviation Administration. Initial work sponsored by this group included evaluations of alternative surfactants, and solvents that are more biodegradable than the ones currently used in AFFFs and bacterial additives. When glycol ethers were put on the list by the Environmental Protection Agency in 1994 as toxic chemicals that required reporting under the EPCRA, the focus of the AFFF replacement program was redirected from improving the biodegradability of AFFF to developing a non-toxic solvent blend. With this development accomplished, work sponsored by the steering group is reverting back to optimizing alternative surfactants and bacterial additives that will make AFFF an even more environmentally friendly foam.

New Insulating Process For Semiconductors Could Lead To Higher-Powered, More-Compact Integrated Circuits

Payoff

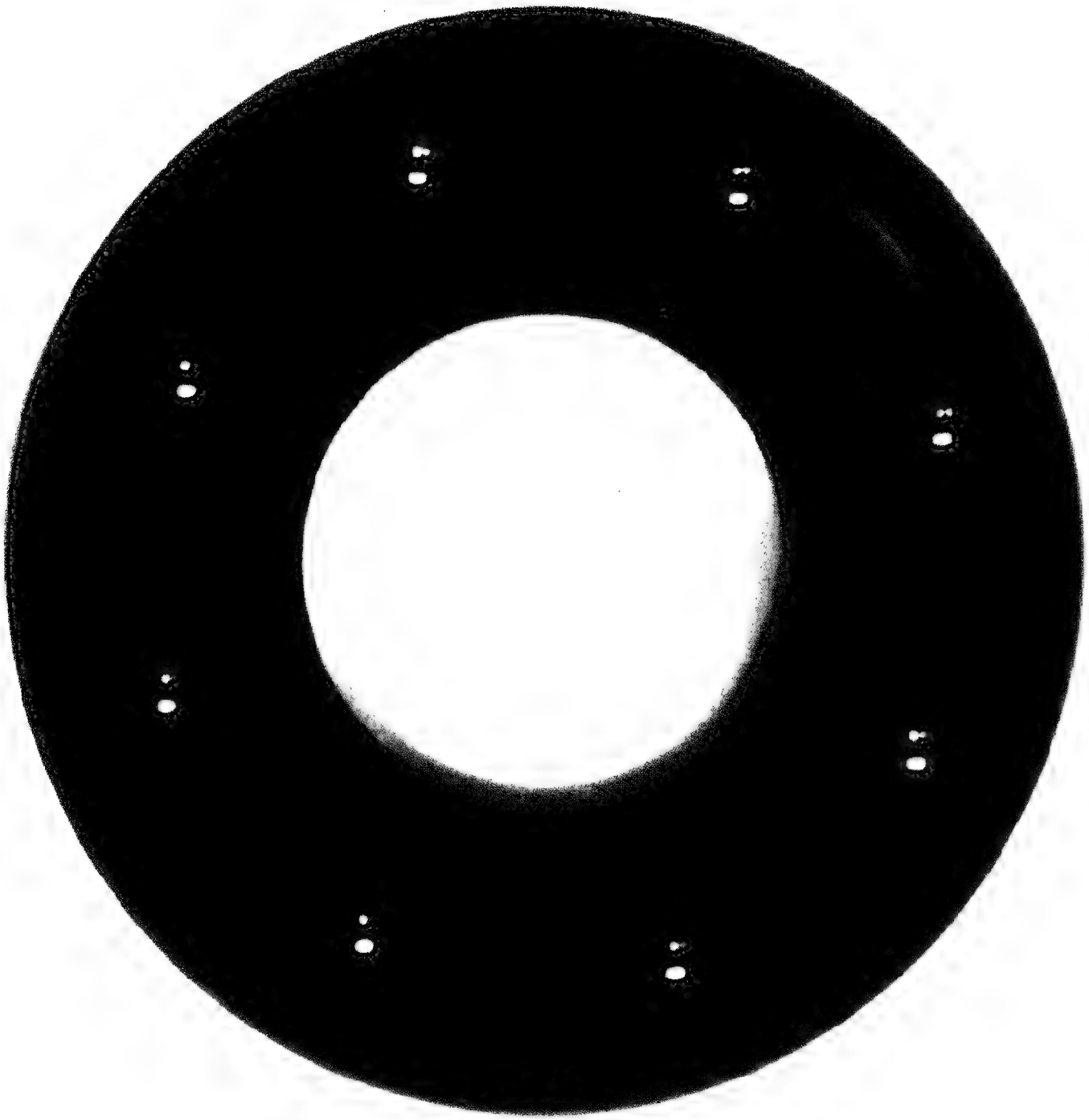
Gallium arsenide semiconductor wafers can be mass-produced with uniform, high structural quality barrier layers of low-temperature gallium arsenide. These gallium arsenide substrates will offer high-power, high-frequency operation in Air Force systems such as extremely high-frequency radio terminals, fiber optic networks, communications satellites, phased array radar systems, airborne laser systems and smart weapon systems.

Accomplishment

Scientists at Wright Laboratory's Materials Directorate developed a process for applying an insulation layer to integrated circuit materials for production of higher-powered, more-compact integrated circuits. Their low-temperature process for depositing a uniform, high structural quality barrier layer of gallium arsenide to semiconductor substrates provides up to 10 times more accuracy for precision production of semiconductor substrates than conventional temperature control methods.

Background

The need to produce faster, more powerful, yet smaller and more compact electronic systems has driven electronic materials research for years. One area of interest is the development of an insulator material for gallium arsenide semiconductor substrates. While integrated circuits based on gallium arsenide semiconductor substrates are currently standard equipment in many aircraft electronics systems, new systems require higher output/operation at higher frequencies than can be provided by ordinary gallium arsenide-based devices. Problems such as sidegating and backgating, low output resistance and low output power gain at RF frequencies result in interference and reduced, erratic operation. A solution to these problems is to deposit a layer of gallium arsenide, produced at low-temperature (200°C), as a barrier between the gallium arsenide substrate and the integrated circuitry. Until now, reproducing the barrier layer production conditions necessary to achieve precise physical properties has been an inexact science. Accurate temperature control is extremely important since low-temperature gallium arsenide properties are dramatically altered with small changes in production temperature. Current techniques, at best, can approximate production temperatures only to within ± 10°C. The new process employs ellipsometry for real-time control of production temperature to within ± 1°C. Ongoing control also permits observation of the state of formation of low-temperature gallium arsenide to anticipate and prevent structural breakdown which could ruin the entire wafer. As a result, gallium arsenide semiconductor wafers can be mass-reproduced that offer performance advances for high-power, high-frequency integrated circuits such as microwave power amplifiers and control circuits; high-power, wide-bandwidth wave sources and ultra-fast and wide-bandwidth opto-electronic detectors.



Diamond-Coated Ball Bearings Last 100 Times Longer Than Steel Bearings

Payoff

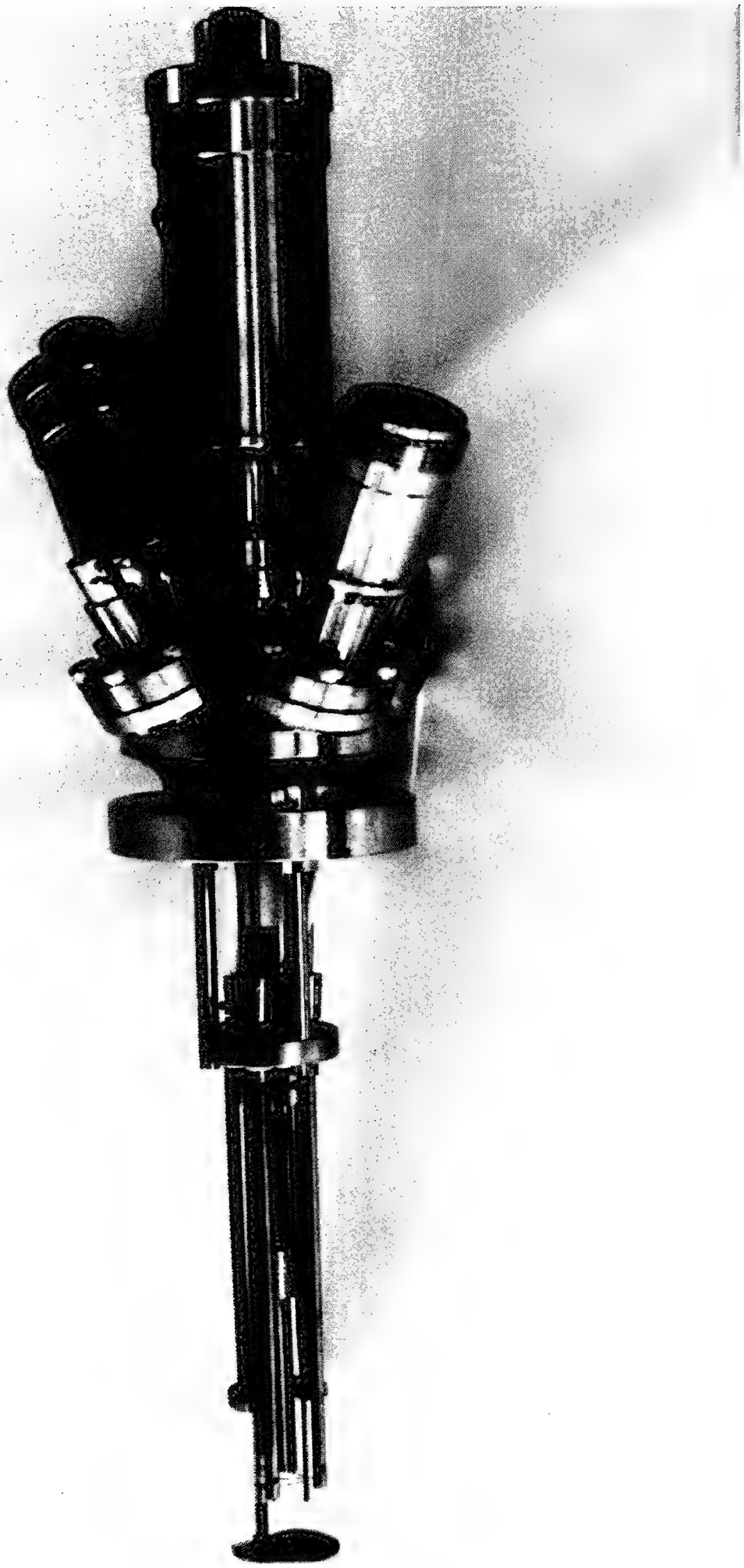
Diamond coating silicon nitride ceramic ball bearings and raceways for high-load, high-temperature applications will significantly reduce, and in some cases eliminate, the need for certain types of maintenance. Diamond coating offers an economical way to improve bearing performance in severe load and thermal applications with long life between lubrication and replacement requirements.

Accomplishment

Ball bearings that last up to one hundred times longer than conventional steel ball bearings have been developed under a program sponsored by the Materials Directorate. These diamond-coated silicon nitride ceramic ball bearings require no lubrication and offer smooth, near-frictionless operation in severe conditions.

Background

From turbine engines to weapon systems to spacecraft components, the dependability of ball bearings often determines the degree of success with which Air Force systems complete their missions. Since ball bearings are subject to load and friction, they must be designed to resist the effects of these forces. Ball bearings have traditionally been made using steel balls and steel races to withstand loads, with lubrication added to reduce friction. In response to more stringent performance demands, hybrid ceramic bearings were developed with ceramic balls and steel races to operate under very heavy loads and in high operating temperatures. While the ceramic bearings can last up to twenty times longer than all-steel bearings, severe applications have evolved that demand even higher performance. The diamond-coated ball bearings developed by Crystallume Corporation, San Jose CA, offer extended performance limits in severe operating conditions. These bearings start with performance-proven silicon nitride ceramic balls and raceways for high-load, high-temperature applications. Controlled carbon deposition is then used to produce a precision diamond film on the surfaces of bearing balls and raceways. Diamond-coated bearings operate with one-tenth of the friction of ceramic bearings, so they can perform smoothly in a range of severe loads and environments. Diamond-coated ball bearings were tested in a tracking system gimbal on a Navy heat-seeking missile. Bearings in this heavy-load application must operate in thermal extremes, with long life between lubrication and replacement. The diamond-coated bearings needed no lubrication or external lubricating system. Time between overhaul for tear-down and bearing replacement was extended to the service life of the missile. Miniature Precision Bearings of Keene NH is working to commercially develop and market diamond-coated ball bearings.



New Source For Growth Of Advanced Transistor Materials

Payoff

An environmentally safe carbon source is now available for the development of advanced transistor materials for both military and commercial applications. The new carbon source is heated by an electron beam to achieve a controlled deposition of a thin material layer for use in advanced transistor materials.

Accomplishment

Under a Small Business Innovation Research (SBIR) program sponsored by the Solid State Electronics Directorate, SVT Associates developed a new and improved source for molecular beam epitaxy (MBE). This carbon dopant source involves controlled evaporation of a carbon or graphite rod by an electron beam for deposition on gallium arsenide (GaAs) and gallium antimonide (GaSb) substrates. The state-of-the-art impurity levels (defect densities) obtained are impressively high: ($5x10^{19}$ cm-3 for GaAs and $3x10^{20}$ cm-3 for GaSb).

Background

The SBIR program with SVT Associates was initiated to develop an environmentally safe, solid carbon dopant source so that semiconductor materials, like GaAs, can have p-type dopants controllably grown in the host material, such as in a heterojunction bipolar transistor (HBT). A HBT is a solid state component used in low-noise and high-power amplifiers and receivers with controllable and predictable optimal performance. The p-type dopants are necessary to create a high gain device. Initially, a p-type dopant called beryllium was used for the growth of p-type GaAs. Beryllium diffuses or moves into the host material causing poor device performance and decreases device reliability. To overcome these problems, a carbon filament dopant source was developed. However, it was unreliable due to its brittleness. The approach using a carbon or graphite rod exposed to an electron beam has proven to be rugged and reliable. The impurity levels obtained are comparable to current dopant levels attained with other gas sources. The developed source has been used by the government, industry and universities.

UNITED STA

WRIGHT LABORATORY TEAM RECEIVES AWARD FOR HALON REPLACEMENT CONTRIBUTIONS

Payoff

The Environmental Protection Agency has recognized the significant contributions made by the team in finding a halon replacement that is effective at extinguishing fires, complies with all national and international environmental legislation and does not produce a significant aircraft performance penalty. Replacement candidates will be made available to commercial aircraft and marine industries and the auto racing community.

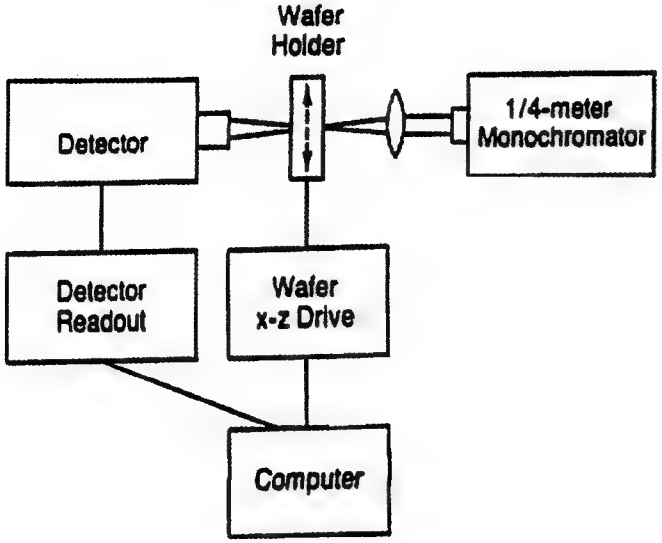
Accomplishment

The Flight Dynamics Directorate's aircraft Halon Replacement Team was presented the 1994 Stratospheric Ozone Protection Award by the United States Environmental Protection Agency. This team, led by J. Michael Bennett from the Directorate's Vehicle Systems Division, received the award for contributions to the elimination of an ozone depleting substance.

Background

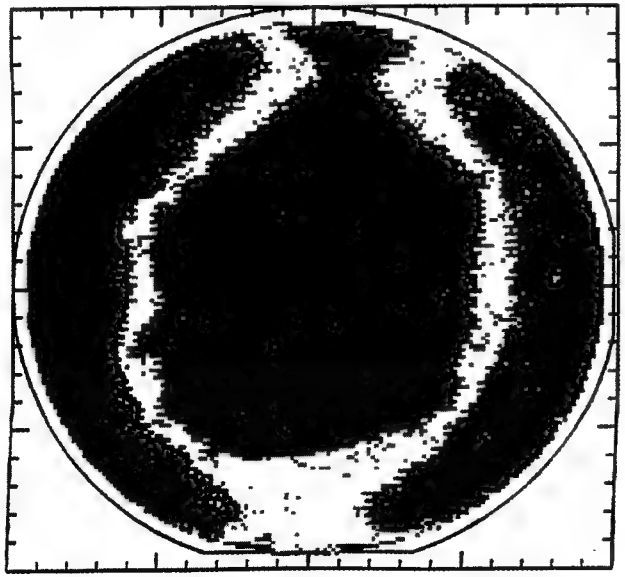
With the end of 1993 came the halt of international production of Halon 1301. Scientific discoveries had determined that chlorinated and brominated compounds, such as halons, are effective in deleting the earth's ozone layers. Stratospheric ozone depletion is predicted to have an adverse global impact on human health, climate and natural ecosystems. Since halons are the primary fire fighting extinguishing chemicals in all Department of Defense (DoD) and commercial aircraft, the Directorate initiated a joint DoD/ Federal Aviation Administration (FAA) three phase program to identify a near-term alternative. During the first phase, researchers determined which parameters in an aircraft fire most influence the amount of agent needed to extinguish that fire. In phase two, three agents were selected by a joint DoD/FAA team from a group of 12 candidate agents tested at the National Institute of Standards and Technology during phase one under laboratory conditions. These three candidate chemicals were subjected to full-scale live-fire testing at Wright Laboratory's Aircraft Survivability Research Facility using the parameters determined in phase one. The outcome of phase two was the selection of the most promising replacement chemical for phase three testing. In phase three, further testing will establish design criteria for the new agent. There are several important considerations in replacing halon in aircraft fire protection systems - chief among them are the weight and volume of the agent and delivery system.

Apparatus

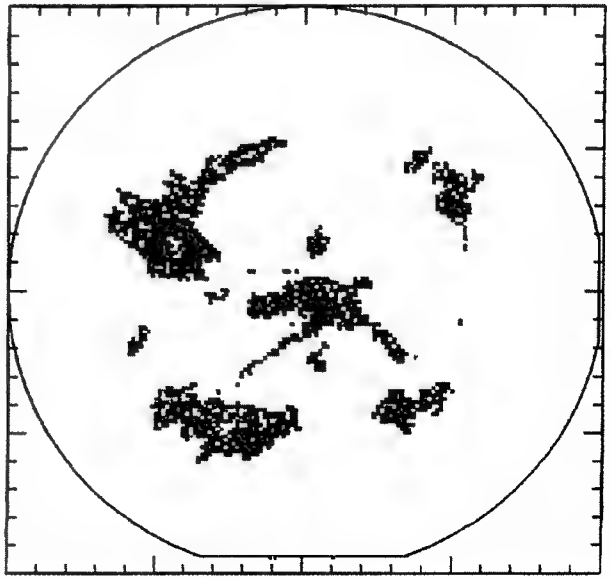


0.90 μm Absorption

1.50 μm Absorption
and
Free Carrier Concentration



Dislocation Density



Nondestructive Technique For Evaluation Of Free Carrier Concentration And Dislocation Density In Doped Gallium Arsenide (GaAs)

Payoff

A nondestructive inspection technique, using transmission maps like those shown left, permits rapid screening of wafers of doped GaAs before fabricating devices on semiconductor materials that may be unsuitable. This technology has enhanced the compound semiconductor industry's predictive and diagnostic materials evaluation capability.

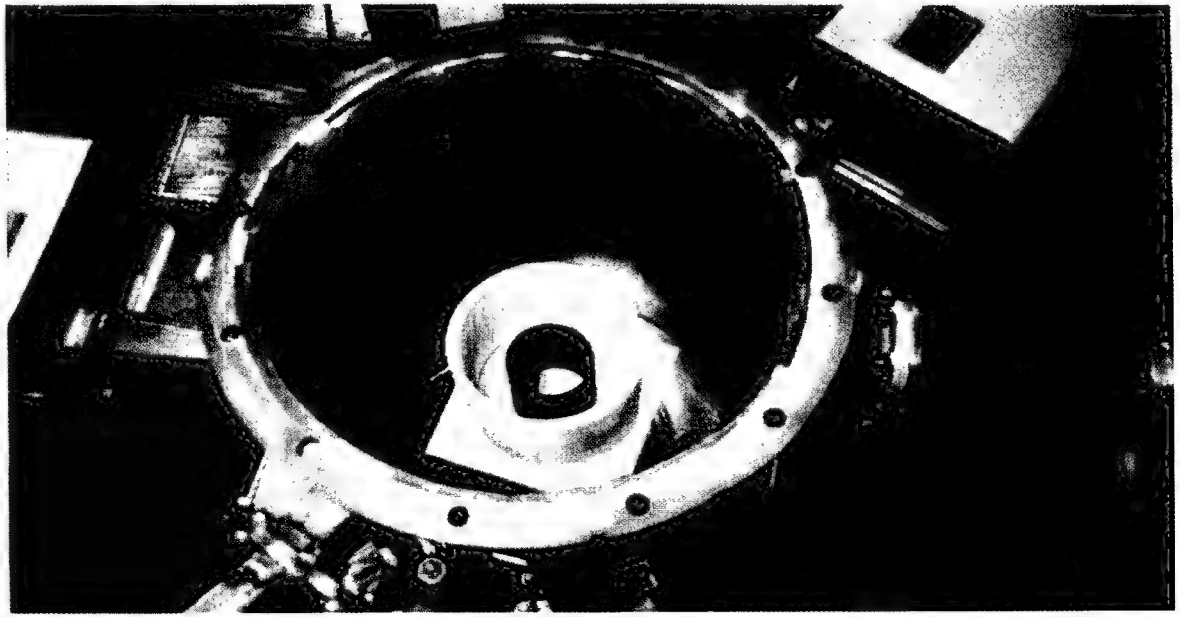
Accomplishment

Solid State Electronics Directorate researchers developed a unique, non-destructive capability to characterize GaAs wafers that is recognized throughout the compound semiconductor industry. Infrared transmission mapping (500 µm x 500 µm resolution) at wavelengths of 0.9-1.5 µm on 3 inch wafers correlated well with the carrier concentration and dislocation density measured by destructive techniques.

Background

For silicon doped GaAs wafers (GaAs:Si), widely used in the fabrication of lasers, solar cells and other devices, very little whole-wafer characterization has been carried out. Two major materials-related difficulties with GaAs:Si are; avoiding any crystalline dislocations and maintaining high free carrier concentration. Dislocations lead to dark-line defects and other dissipative defects which are harmful to lasers. Maintaining high free carrier concentration produces two desirable device properties, namely, low series resistance and good ohmic contacts. All previous techniques for measuring free carrier concentration and mapping dislocation density damage the wafer. Hall effect measurement of free carrier concentration requires small pieces and contacts to the piece. Dislocation density measurement generally requires etching the wafer and counting etch pit density. The Solid State Electronics Directorate researchers demonstrated that both free carrier concentration and dislocation density can be precisely mapped nondestructively in doped GaAs wafers. The infrared transmission through the wafer at one wavelength (1.5 µm) was correlated to the free carrier concentration and at another wavelength (0.9 µm) to the crystalline dislocation density.

Assembled microwave system (control box, cavity, and six magnetrons).



Interior of the microwave cavity (four inch diameter, 6" long combustor can).

Microwave Chemical Vapor Infiltration (MWCVI) Process Improves Ceramic Matrix Composite Parts

Payoff

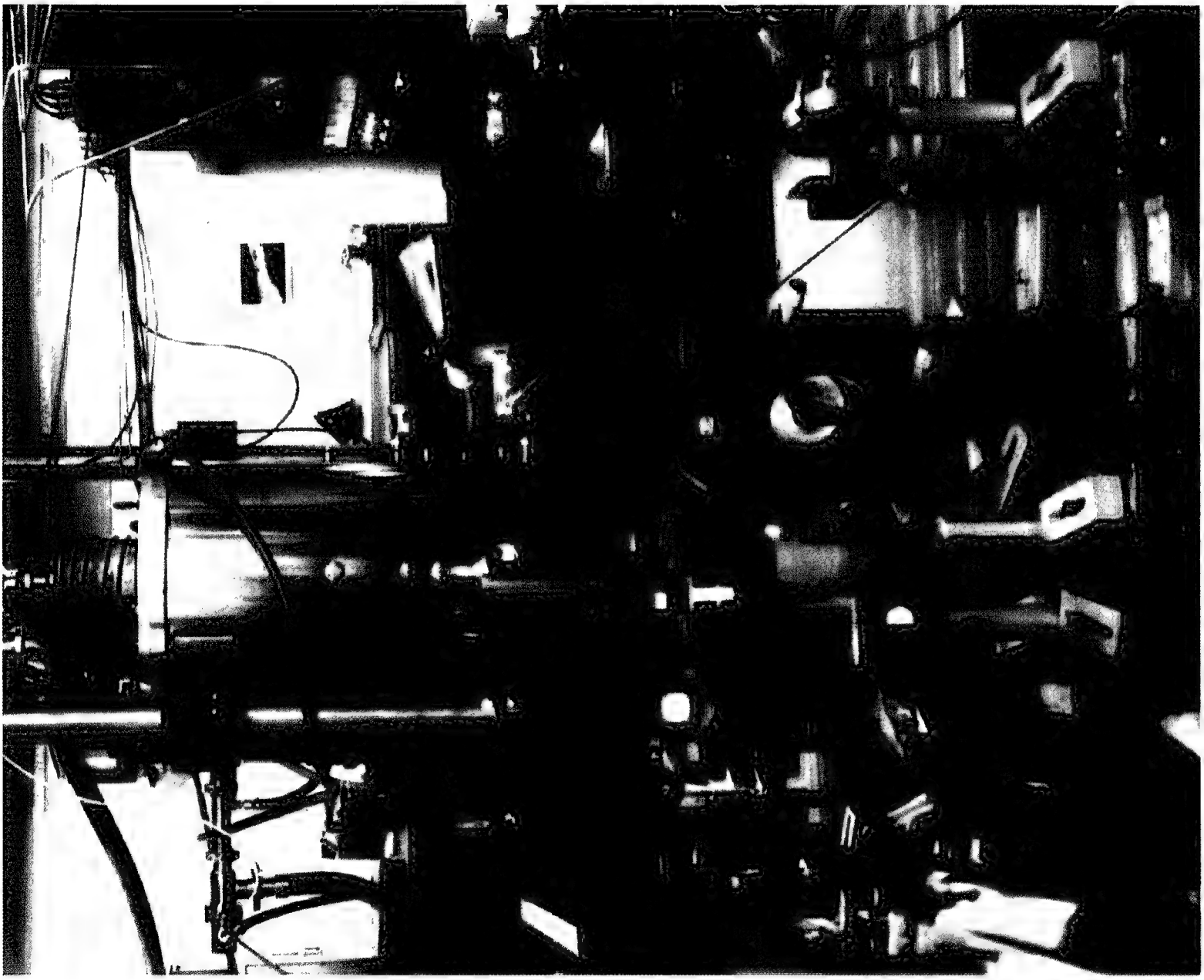
The MWCVI process will enable the production of larger thickness ceramic matrix composite parts than are possible with conventional CVI methods. The process requires less raw material and less time for densification of the fiber preform resulting in a fabrication cost reduction of over 40%. The assembled microwave system, including the microwave cavity, six magnetrons and control box, is shown left.

Accomplishment

Under a Small Business Innovation Research (SBIR) Program, sponsored by Wright Laboratory's Aero Propulsion & Power Directorate, the feasibility of microwave-assisted chemical vapor infiltration for fabricating low cost ceramic matrix composite (CMC) parts was demonstrated. With MWCVI, process time is decreased from hundreds of hours to tens of hours, and material density is more uniform. The amount of reactant gas needed is decreased significantly due to more efficient deposition of the gas on the fiber preform.

Background

The use of advanced CMCs has been plagued by the high cost of component materials and the long processing times required to densify the fiber preforms which results in high fabrication cost. In conventional CVI, the preform is heated from the outside so that the densification reaction occurs at the surface. The surface soon plugs up so that no more reactant gas can get into the center of the preform; therefore, part thicknesses are limited. With microwaves, heat is generated internally so that densification occurs from the inside outward toward the surface making thicker parts possible. Under the Ceramic Composite Combustor Cans for Expendable Turbine Engines SBIR program, Ceramic Composites, Inc. was able to demonstrate several payoffs from using MWCVI technology over conventional CVI such as more uniform part density, decreased processing time, reduced amounts of raw material needed and significant cost savings. Also, because the matrix precursor is deposited on the preform more efficiently, so that less of it is wasted, MWCVI is a much more environmentally friendly process.



Intelligent Control Of Coating Process For Lightweight Turbine Engine Components Improves Thermal Protection

Payoff

Intelligent control of a chemical vapor deposition process provides precision deposition of the crystalline form of silicon nitride for coatings that offer thermal protection of carbon-carbon turbine engine components in temperatures as high as 3200°F.

Crystalline silicon nitride coatings will allow the use of weight saving material in cruise missile engines to help provide a 55 percent increase in missile operating range.

Accomplishment

Materials Directorate and United Technologies Research Center researchers collaborated to develop intelligent control of a chemical vapor deposition process for precision coating of carbon-carbon turbine engine components. On-line, real-time measuring offers precision thickness control to ±5 percent, even with coatings as thin as two thousandth of an inch.

Background

To meet increased performance demands for Air Force weapon systems, innovative component materials are being developed under the Integrated High Performance Turbine Engine Technology (IHPTET) initiative. High performance goals for turbine engines in all military aircraft have been set including a 55 percent operating range increase for Air Force cruise missiles. The most direct way to achieve this goal is to reduce component part weight without compromising performance. In one weight-savings application for the cruise missile engine, a metallic bladed rotor will be replaced with a bladed ring made of advanced, three-dimensional weave carbon-carbon. While this lightweight material can meet performance demands, it needs protection against high temperatures which cause oxidation and severe degrading of the part. A crystalline silicon nitride coating can provide that protection. Since the thermal expansion rate of crystalline silicon nitride is very close to that of carbon, the coating will not work loose and break off through typical engine cycles of hot and cold. Achieving the crystalline form of silicon nitride in coating deposition depends on intelligent control to maintain an application temperature above 1400°C, as well as controlling the deposition rate. At lower temperatures and deposition rates the material structure remains uncrystallized, which results in a coating with oxidation resistance and lessened structural stability at elevated temperatures. Intelligent control of the coating process is achieved by use of a non-contact laser ultrasonic sensor system for in-processing evaluation of coating thickness, linked to the coating equipment to maintain precision deposition rates. The coating process and intelligent control are being transferred for use in a manufacturing-scale reactor at the Amercom Corporation, Santa Ana CA.

ELECTRICALLY POWERED ACTUATION DESIGN (EPAD) VALIDATION FLIGHT TEST PROGRAM TEAM RECEIVES LAURELS

Payoff

Replacing hydraulic systems on aircraft with a flight control actuator powered by electric motors will greatly simplify flightline maintenance, enabling the frequency of aircraft sorties to increase. The successful flight test of the smart actuator is the first step toward this goal. This flight test validated the survivability of control electronics in the severe environment in which the actuator will operate. The application of smart actuator technology to actuation devices will reduce flight control computer complexity and improve the monitoring of actuation integrity.

Accomplishment

The EPAD validation flight test program team was recognized by Aviation Week and Space Technology in January 1995 for contributions in the electronics field of aerospace. This joint Air Force/National Aeronautics and Space Administration (NASA)/Navy team, led by the Flight Dynamics Directorate, received the 1994 Aerospace Laurel Award for a flight test of a smart actuator. The application of control and monitor electronics local to the flight control actuator on the aileron control surface of a F/A-18 aircraft was successfully demonstrated.

Background

Current flight control actuators depend on the central hydraulic system for power to move control surfaces and on the flight control computer for electronic logic to provide accurate surface positioning. Improved performance of future/ derivative tactical fighter aircraft will increase actuator requirements. Electrically powered actuators and incorporation of local actuator control are two ways to eliminate problems associated with central hydraulic systems (leakage, maintenance, vulnerability, etc.). A memorandum of agreement between the Air Force, Naval Air Warfare Center and NASA Dryden, resulted in each participant contributing resources that enabled flight test of the smart actuator on the aileron control surface of NASA's F/A-18 systems research aircraft. Most of the preliminary development of the actuator was accomplished for the Navy by H. R. Textron, Valencia CA using Navy and independent research and development dollars. The final form of the smart actuator, including closed loop fiber optic communication, was delivered to the Navy in 1991. Flight testing commenced in April 1993 and concluded in November 1993. The smart actuator performed flawlessly during 33 flight test hours. Pilots of the F/A-18 said they could not differentiate between the performance of a traditionally-powered actuator and the EPAD smart actuator.

Materials Research Provides Quick Solution To F-15 Fuel Leakage Problem

Payoff

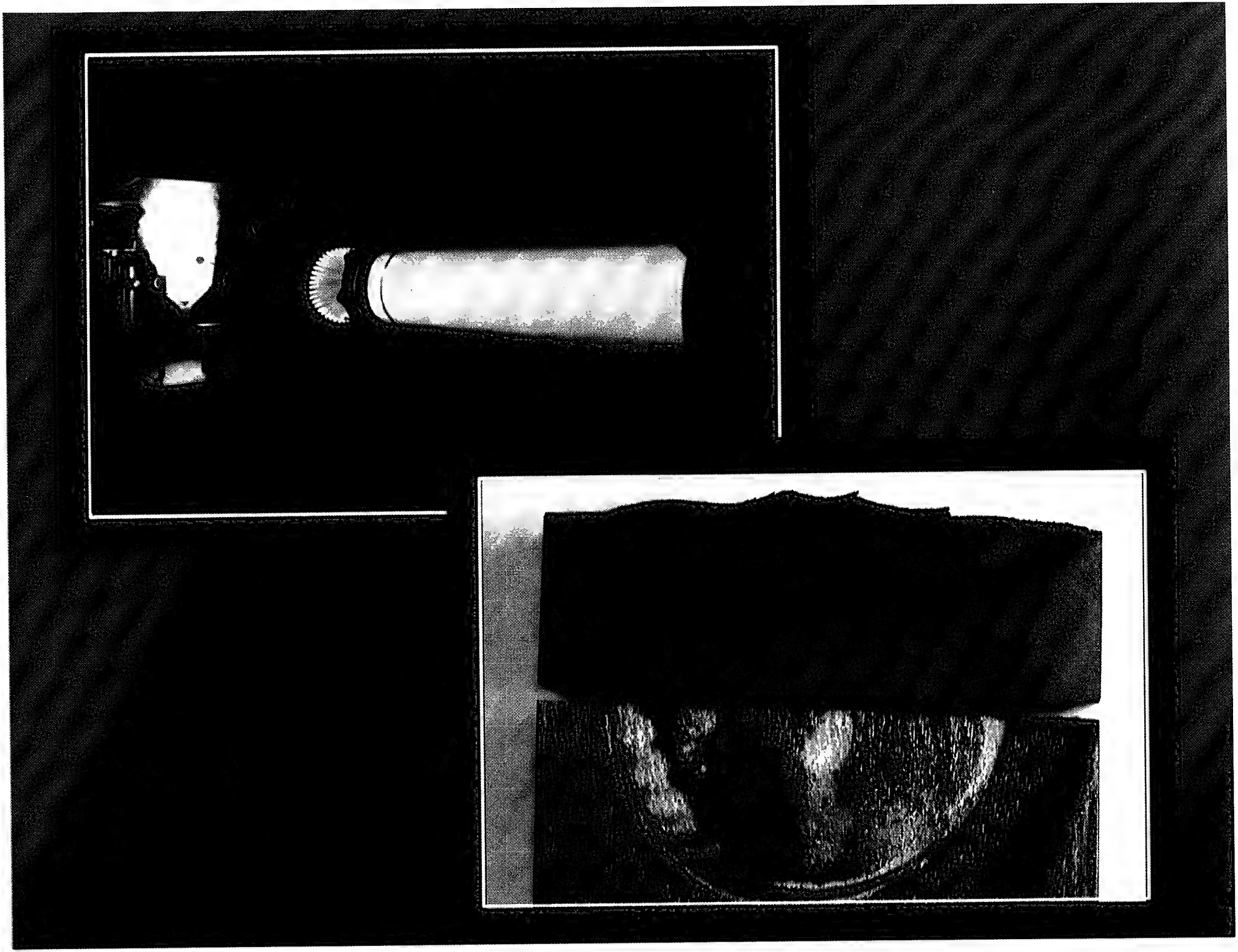
Replacing the fluorosilicone sealant used in the F-15 wing fuel areas with new polysulfide sealant eliminated a fuel leakage problem and returned Nellis Air Force Base F-15s to full operational status. This enabled test exercises and weapons and tactics training classes to proceed as scheduled.

Accomplishment

Researchers at Wright Laboratory's Materials Directorate, working with engineers from Warner Robins Air Logistics Center, Air Combat Command and McDonnell-Douglas, solved a fuel leakage problem on the Air Force's F-15 aircraft. By avoiding costly disassembly, their quick analysis and approach to solving the problem proved to be more than 90 percent faster than previous repair methods. Within three months, 97 percent of the affected aircraft at one Air Force base were returned to fully operational status.

Background

To lessen the potential hazard from fuel during flying operations, the Air Force switched from JP-4 fuel to less volatile JP-8 fuel. While improving operational safety, some Air Force aircraft experienced fuel leakage problems as a result of the switch. Within four months after the change, 37 of 39 F-15s at Nellis AFB NV were restricted from flight due to fuel leaks in the wings. These leaks occurred in the fuel areas that had been sealed with a fluorosilicone sealant injected into a groove. A similar leakage problem had been seen by Materials Directorate engineers seven years earlier when several Air National Guard (ANG) F-15s had been fueled with JP-5, a fuel with many of the characteristics of JP-8. At that time, an in-house investigation determined that fuel-induced sealant shrinkage caused the leakage, which led to the development and testing of compatible sealants. In the case of the Nellis F-15s, the problem was exacerbated by previous over-pressure application of sealant into the grooves. This caused gaps which permitted the sealant to escape from the grooves. The polysulfide-based sealants, developed earlier as a result of the investigation of the ANG's F-15s, proved effective in filling the gaps, adhering to interior wet surfaces and resisting fuel-induced shrinkage. Improved sealant application techniques were developed to assure precision injection, an operation requiring about two days per plane. Without the polysulfide-based sealant, the leading edge of each wing would need to be disassembled, the channels cleaned and new sealant injected--an operation that would take nearly three weeks work per plane. Follow-on work performed by Materials Directorate and Air Logistics Center engineers has resulted in the development of a successful repair program for all F-15s that includes the new sealant and improved sealant application techniques.



150 Kilowatt Laser Reduces Cost Of Composite Material Thermal Testing

Payoff

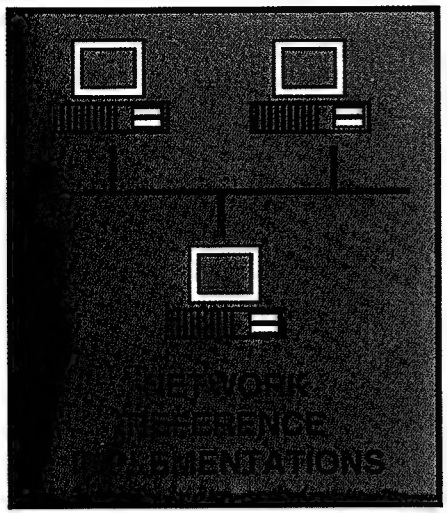
In simulating the thermal conditions inside a solid rocket motor, the 150 kilowatt laser proved its value and versatility as a tool for isolating and quantifying thermomechanical events in material evaluation. Accurate selection of nozzle thickness and material configuration can now be made for a fraction of the cost of traditional methods.

Accomplishment

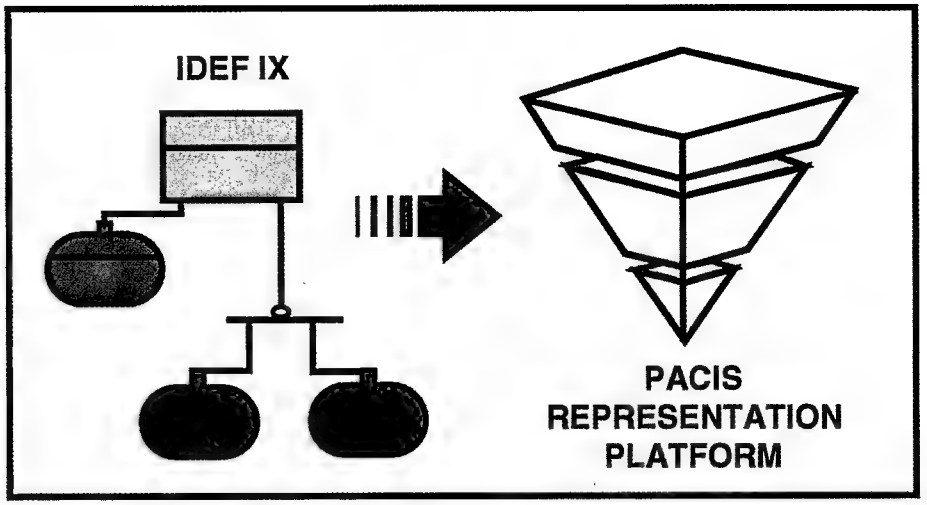
Materials Directorate engineers assisted Southern Research Institute of Birmingham, AL and Physical Sciences Inc. of Andover, MA in reducing the cost of testing composite materials used for nozzles on solid rocket motors by over 99 percent. Using the Directorate's 150 kilowatt laser, they configured a reproducible, controllable and affordable testing environment capable of simulating the thermal conditions inside a solid rocket motor nozzle during firing. The laser test established the range of ply lifting material response as a function of heating rate, and proved that ply lifting failure mode can be readily reproduced in controlled laboratory conditions.

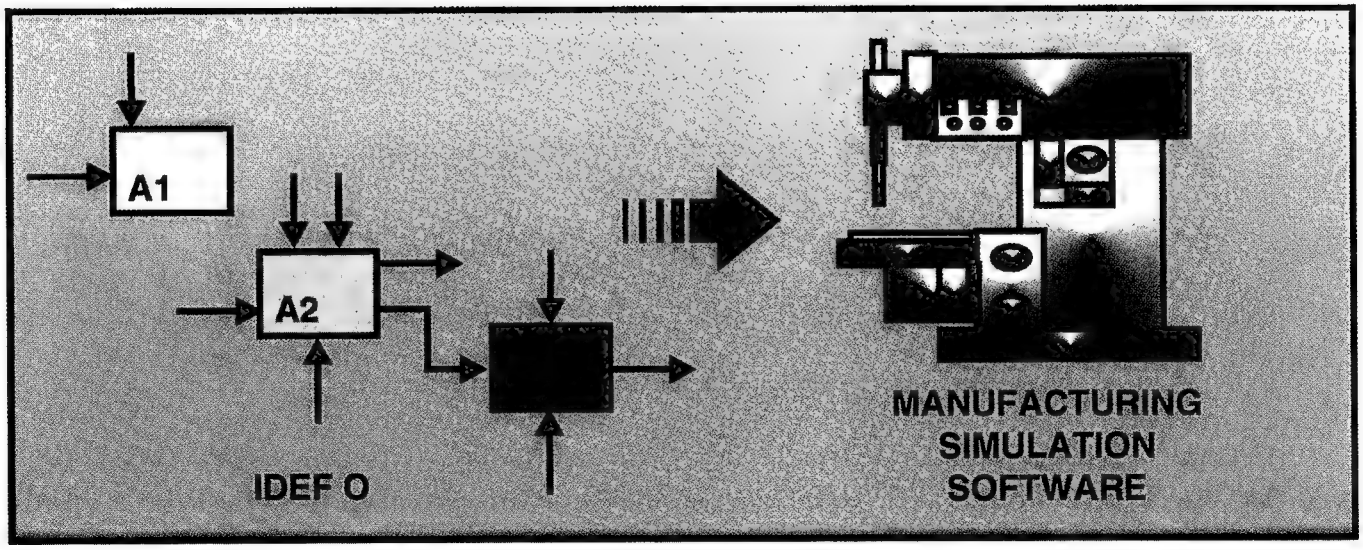
Background

Solid-fuel rockets use carbon-phenolic composite nozzles to focus and direct hot exhaust gases. Some charring and lifting of plies in the composite material is expected and acceptable during firing, but too much leads directly to nozzle failure. Nozzle thickness is critical -- excess thickness adds costly weight and reduces payload; not enough thickness destroys the nozzle and its usefulness. Traditionally, testing with data-gathering instrumentation on the nozzle has involved solid rocket motor ground-firing. The cost of each firing is $2 million, and all too often, nozzles and instrumentation have been consumed, making it difficult to quantify test results. In comparison, the Directorate's Laser Hardened Materials Evaluation Laboratory (LHMEL) facility provided a testing environment capable of simulating the thermal conditions inside a solid rocket motor nozzle during firing. The facility's 150 kilowatt continuous wave carbon dioxide laser provides a large, uniform flat-top beam profile. As material is irradiated, its surface temperature can be precision-controlled within a range of ±20°C. For the nozzle composite, 22 tests were conducted on eight material configurations to determine the relationship of test sample ply lifting and charring to that seen in actual nozzles. Four irradiation levels produced surface temperatures as high as 1300°C. The controlled laser exposures, as well as the combination of the range of specimens and visualization techniques, allowed thorough investigation of the modes of material response. The LHMEL facility provides unique opportunities for the application of laser technology to a broad range of test requirements.



INTEGRATION TOOLKIT





Integrated Toolkit And Methodology (ITKM) For Aerospace Manufacturing Developed

Payoff

The methodology to improve and develop integration technology will enable the Department of Defense and industry to keep pace with the ever increasing complexity of computer systems that support manufacturing processes. The impact on integration efforts and modeling methodologies has resulted in several actual manufacturing systems for prototype gears and projected reductions of 20-30 percent in distributed system development times.

Accomplishment

Under a project sponsored by the Manufacturing Technology Directorate, a set of integration tools was developed that enhance and compliment the current set of Integrated Computer - Aided Manufacturing DEFinition (IDEF) Languages. These tools enable simulation of a complete manufacturing process, design and test of networking protocols and a data representation for all phases of a system's development life cycle.

Background

Three programs were initiated under the Integrated Toolkit and Methodology Project to examine ways to improve database management, network development and information systems for manufacturing. Under the Manufacturing Methods and Prototype Toolkit Program, Industrial Technology Institute developed a manufacturing systems design method called XSpec® which significantly reduces the time and cost to create complex prototype gears. XSpec® models simulate the complete manufacturing process which allows the designs to be tested and validated before committing to implementation. Under the Automated Protocol Analysis/Reference Tool Program, Corporation for Open Systems International developed a rapid prototyping program called ENGAGE to design and test protocols for networking. Using a graphical representation for each state in the network, ENGAGE allows developers to simulate and test the compatibility of different computer systems and communication protocols throughout the network to ensure proper connectivity. After a complete analysis, ENGAGE then automatically produces the proper protocol for the network. A third program, Corporate Data Integration Tools, provides a user friendly design interface to the Platform for the Automated Construction of Intelligent Systems (PACIS™) product to develop executable representation code. This code provides an aggregation which allows the tools to share the information and data derived from each information system model. The Corporate Data Integration Tools Program has been transferred to system analysts at Northrop, Westinghouse and Alcoa.

SCANNING RADIOMETRIC IMAGER (SRI) SYSTEM CHARACTERIZES CANOPY LASER SCATTER

Payoff

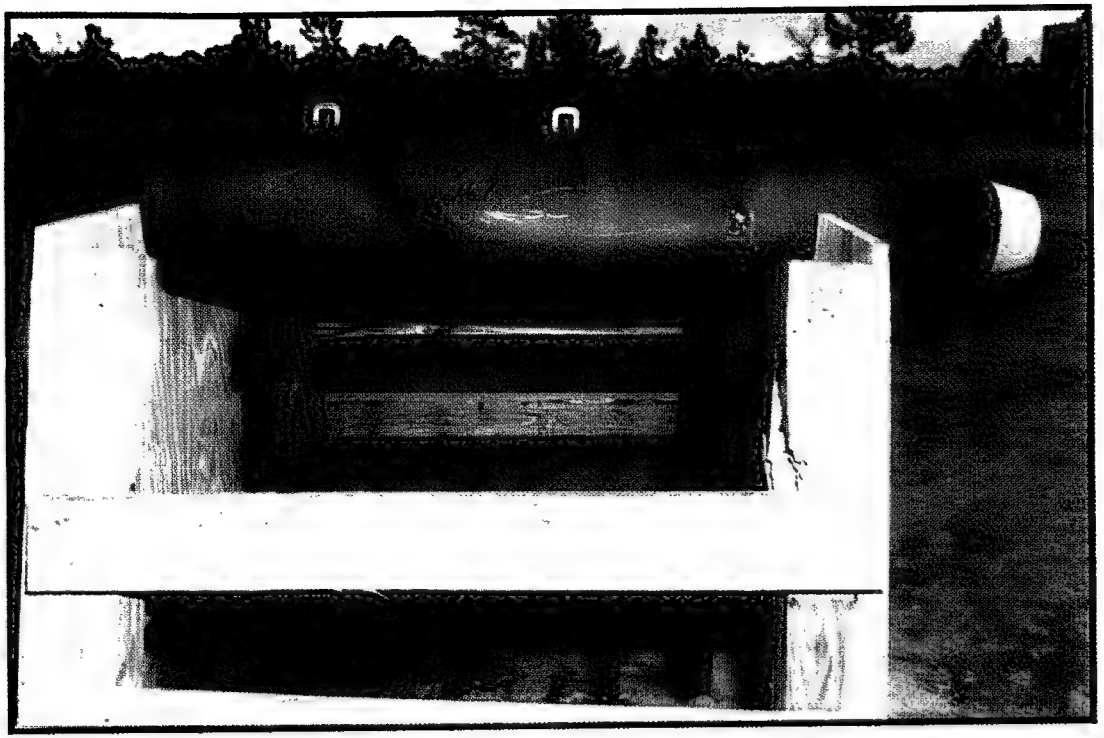
Using the SRI to characterize canopy laser scattering will enable the development of eye protection and countermeasure technologies for use against anti-personnel laser weaponry. This measurement device will provide a critical data base for the development of eyewear, laser warning sensors, canopies and mission tactics.

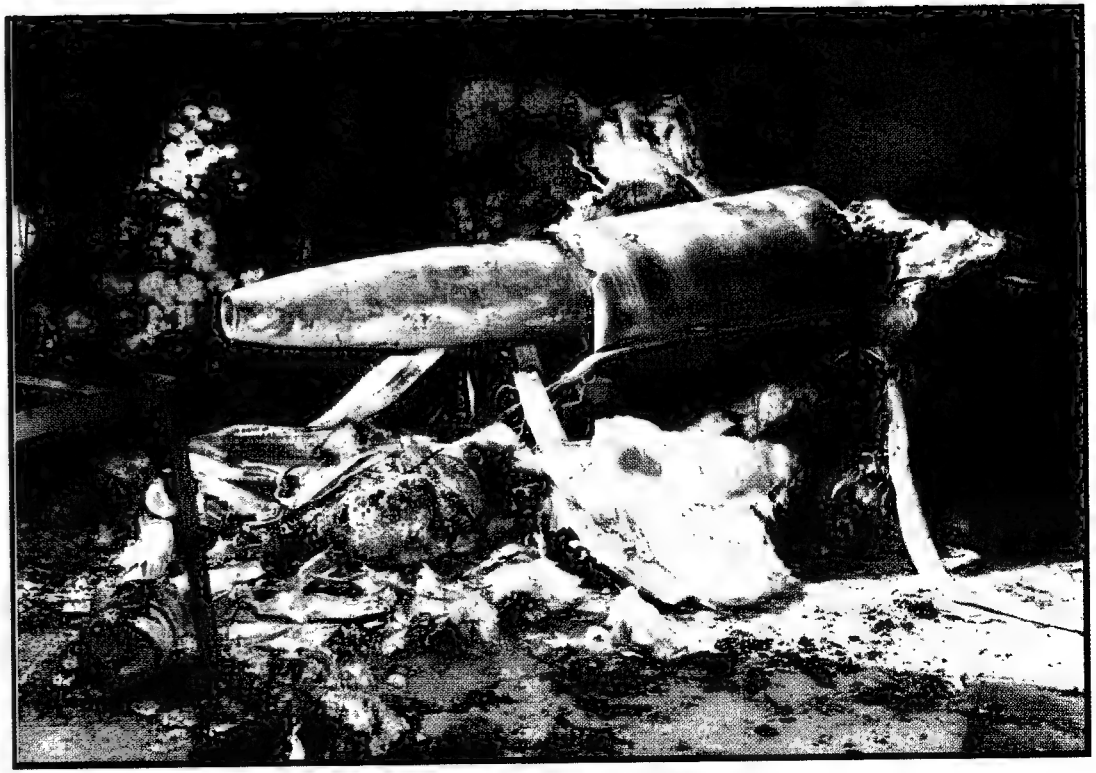
Accomplishment

Wright Laboratory's Avionics Directorate developed in its Laser Sensor Technology Lab Facility a high-resolution, radiometric scanner for collecting laser scatter data from aircraft canopies. The SRI system supports eye modeling and psycho-physical studies at Armstrong Laboratory. It is capable of collecting radiometric and photometric imagery over a 40 degree viewing angle, with 0.15 degree resolution while maintaining a large optical dynamic range.

Background

The emerging electro-optical threat harbors the potential for anti-personnel laser weaponry. This potential has prompted the search for an understanding of how such weaponry might affect aircrew missions, as well as the required countermeasures and warning technologies. In pursuit of this understanding, is the need for accurate characterization of the optical artifacts (scatter profiles) associated with cockpit illuminations. The Avionics Directorate was tasked by the Air Staff to investigate experimental methodology for acquiring radiometric data from aircraft canopies that is suitable for eye model validation. The challenge was to design an acquisition system which would not produce self-induced artifacts in the imagery over a large optical dynamic range requirement. The instrument was to measure narrow ray bundle intensities from physical points of scatter around the canopy, to hand-off to ray tracing modeling being developed by Armstrong Laboratory. Four design iterations led to an acceptable design, incorporating all reflective optics. The parabolic collecting optics were designed to permit wide angle scanning with high fidelity instantaneous resolution. A user interface allows the operator to specify various measurement modes, scan limits and resolution and it provides quick-look, false colored images during acquisition. The finished device is configured to sit in the cockpit seat and observe from the pilot's point of view. SRI is being utilized to validate F-16 mock-ups at Armstrong Laboratory. The device will undergo field trials in a full-scale aircraft turntable facility to generate data that will be utilized in an Air Staff sponsored flight test scheduled for late summer, 1995.





INSENSITIVE EXPLOSIVE MIXTURE MAKES BOMBS SAFER

Payoff

Utilization of a new explosive mixture in the Fuzed, Insensitive General Purpose Bomb (FIGPB) system enabled 500 pound FIGPB systems to survive bullet impact tests (left top) and to pass slow cookoff qualification tests without detonating (left bottom).

The insertion of this technology into future bomb systems will enhance munition maintenance, operational safety and eliminate system vulnerability to accidents and sabotage.

Accomplishment

The Armament Directorate's Munitions Division demonstrated a technology that reduced the sensitivity of a MK-82 general purpose bomb, while achieving reliable initiation with existing fuze technology and maintaining lethality. The FIGPB system utilized a new explosive mixture designated AFX-645 that is nearly 9 times less sensitive to shock than the current explosive used in the MK-82.

Background

Munitions-related accidents have cost U.S. forces hundreds of lives and nearly 1 billion dollars since the mid-1960s. The FIGPB system integrates the insensitive AFX-645 high explosive and a robust initiation system into a MK-82 general purpose bomb. AFX-645 is nearly 9 times less sensitive to shock than the current explosive used in the MK-82 with comparable performance characteristics. This low sensitivity means that an intentional detonation of a single FIGPB while stored in a standard munition rack, will not cause detonation of the surrounding FIGPBs even if they are fully assembled. AFX-645 complies with the United Nations criteria for extremely insensitive detonation substances as well as the full scale insensitive munition criteria for slow cookoff and bullet impact. The FIGPB's mild response to exposed fire is a first for a fully assembled general purpose bomb system. The initiation system, derived from the standard FMU-139 fuze, consists of an innovative combination of PBXN-7 and PBX-9502 boosters that provide the exceptionally high levels of energy required to initiate explosion of the AFX-645 while maintaining insensitivity for the overall system. This technology is ready for introduction into the next generation of weapon systems and is being employed in upgrades to existing ammunition systems such as the 105mm gun.

Air Force Office Of Scientific Research (AFOSR) Star Team Award

Payoff

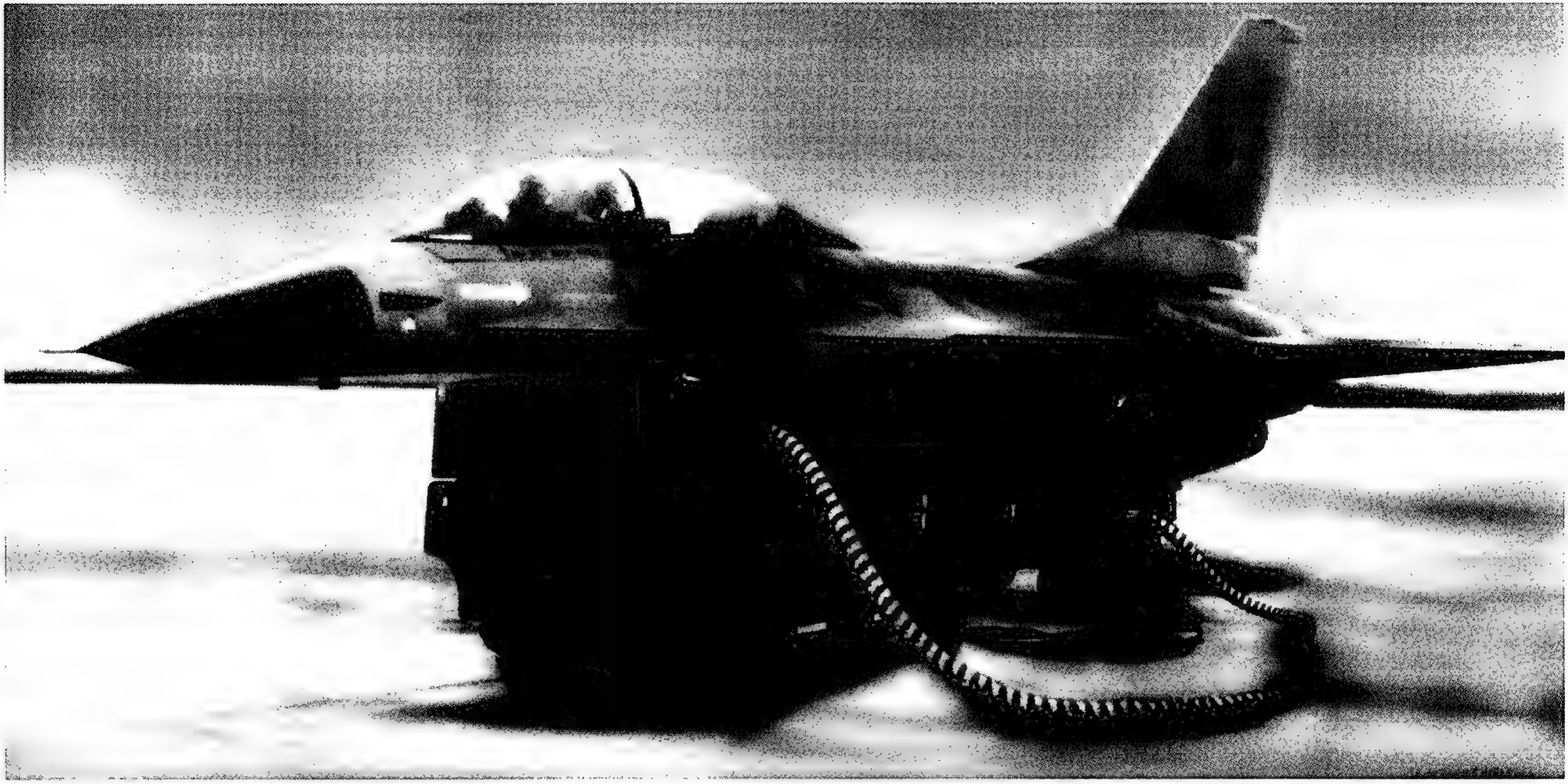
The AFOSR Star Team Award fosters excellence within the research community and highlights the critical role of basic research within the Air Force's broad technology spectrum. The 1994 Wright Laboratory Star Team strengthens the role of basic research within the Air Force Science and Technology program by showcasing achievements in the area of material surface phenomena.

Accomplishment

A team of researchers led by Dr. T. Walter Haas of the Materials Directorate received the 1994 Air Force Office of Scientific Research Star Team Award. The award is based on the team's contributions to the understanding of the unique solid surface and thin film phases of materials whose properties affect a broad range of Air Force applications. The award rewards teams of researchers that have proven, through their track record, world class status and excellence in their chosen areas of basic research.

Background

The research goal of Dr. Haas and his team is to understand and control surface and thin film phenomena to provide advanced materials systems for a wide range of Air Force applications with particular emphasis on tribology (lubrication and wear-resistant coatings). The team developed a new material, carbon nitride (CNx), which is theoretically predicted to be potentially harder than diamond. The material was grown using reactive magnetron sputtering and by reactive pulse-laser deposition. Characterizations of these films show that they are environmentally stable, possess high hardness and offer promising tribological properties. Their understanding of friction and wear at a molecular level has permitted the designated growth, by pulse laser deposition, of ultra low friction solid lubricant films and self-forming, composite-adaptive solid lubricants. These adaptive lubricants have proven "reversible" in their effectiveness, allowing them to cycle between both low and high temperature ranges. Research showed that optical sensing of plume dynamics can lead to significant improvements in pulsed laser deposition rate and film properties. This work is currently being transitioned to local industry. Dr. Haas's teams work in Nanoscopic Surface Preparation (NSP), which involves surface preparation by diamond turning, has the potential to be a unique thin film surface preparation technique, as well as, a mechanical lithography for advanced electronic devices. Advanced X-ray diffraction and optical techniques have been used to characterize subsurface damage in single crystal substrates following NSP in preparation for future thin film growth experiments.



Fuel Leakage Problem On Aircraft Ground Power Generation System (GPGS) Units Solved

Payoff

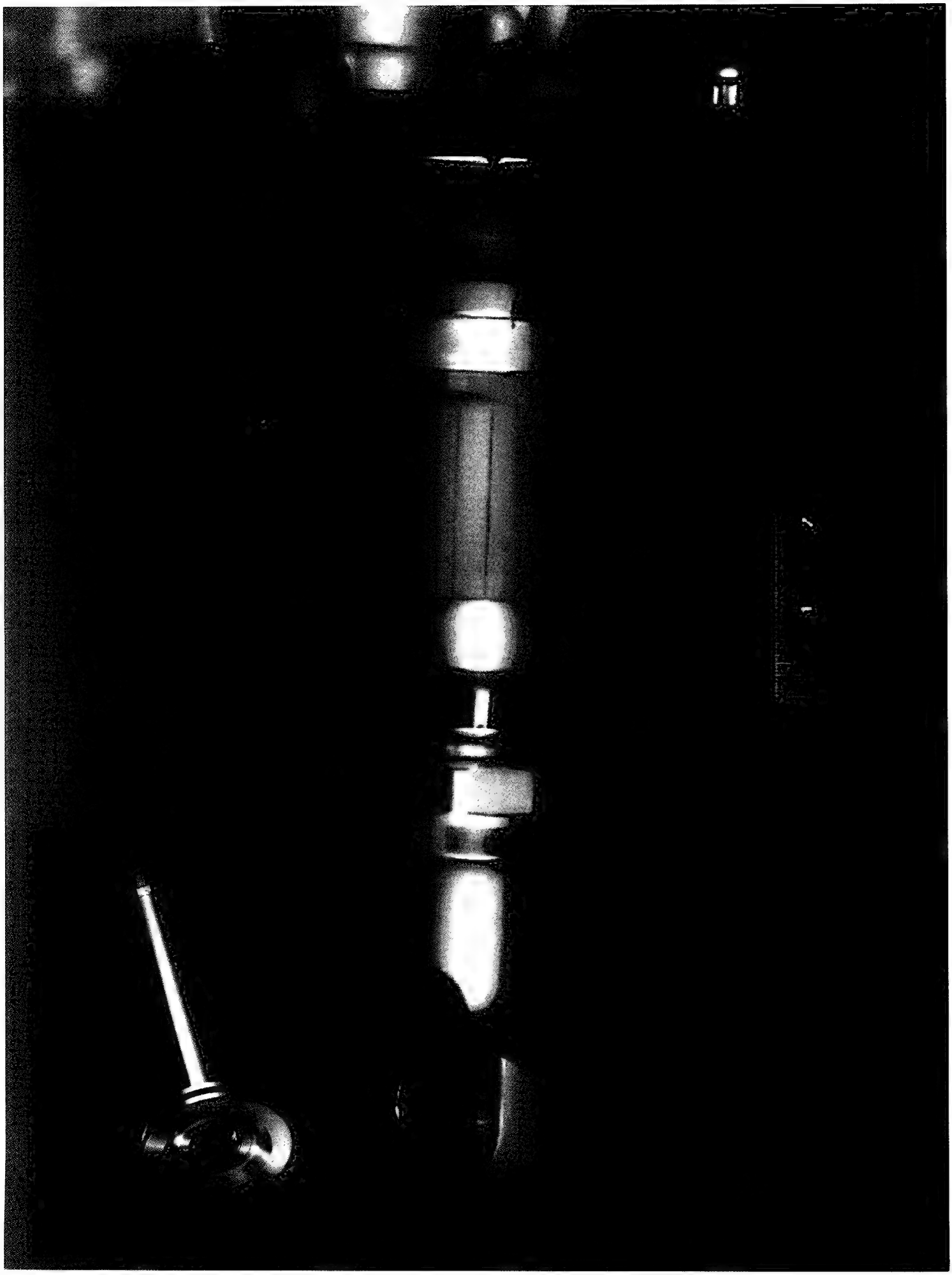
The Materials Directorate's teaming with the Aeronautical Systems Center to solve a GPGS unit fuel leakage problem permitted rapid deployment of safe, high-quality GPGS units. The utilization of stabilized stainless steel and special welding techniques for these units eliminated a serious safety problem and made it possible for the ground power unit to be quickly returned to service.

Accomplishment

Engineers from Wright Laboratory's Materials Directorate and Aeronautical Systems Center's Aeronautical Equipment Systems Project Office teamed to solve a fuel leakage problem on portable GPGS units that provide conditioned air and electrical power for Air Force aircraft. They performed a failure analysis, recommended corrective steps and developed qualification procedures that eliminated a major safety problem. Compressed and conditioned air are required to start aircraft

Background

turbine engines. External electric power is needed during maintenance and preflight checks when the engines are shut off. To accomplish both of these tasks, GPGS units are used. For many years GPGS units were diesel-powered. They were difficult to start and required a special type of fuel. Their deficiencies led to the development of a unit powered by a regenerative gas turbine capable of achieving the output capability and reliability goals required for advanced aircraft. Yet when the new GPGS units were undergoing field tests, the stainless steel fuel tanks sprang multiple leaks. The team found that fuel tanks on earlier GPGS units used flat flanges that were welded. The particular type of stainless steel being used, 304, couldn't take the heat generated during welding. Carbide precipitation caused by the welding heat led to metal sensitization, microcracking and corrosion at the welds that resulted in fuel contamination and leakage. Use of an incorrect welding specification resulted in lack of penetration, undercuts and porosity at unacceptable levels. Inspection of the fuel tanks on the entire inventory of field 365 gas turbine units indicated that 50 percent were defective due to poor quality welds. Since a leaking unit could possibly damage the aircraft it was intended to service, this was considered a major safety issue. Materials Directorate engineers recommended changing to a stabilized grade of stainless steel such as 304L, and changing the welding specification to one specifically designed for the welding of stabilized stainless steel. In the process, a new tank manufacturer was selected and improved manufacturing procedures were employed. Mini-qualification procedures developed by Materials Directorate engineers helped quickly return the previously defective tanks to service.



TITANIUM MATRIX COMPOSITE REDUCES WEIGHT OF F-22 AIRCRAFT

Payoff

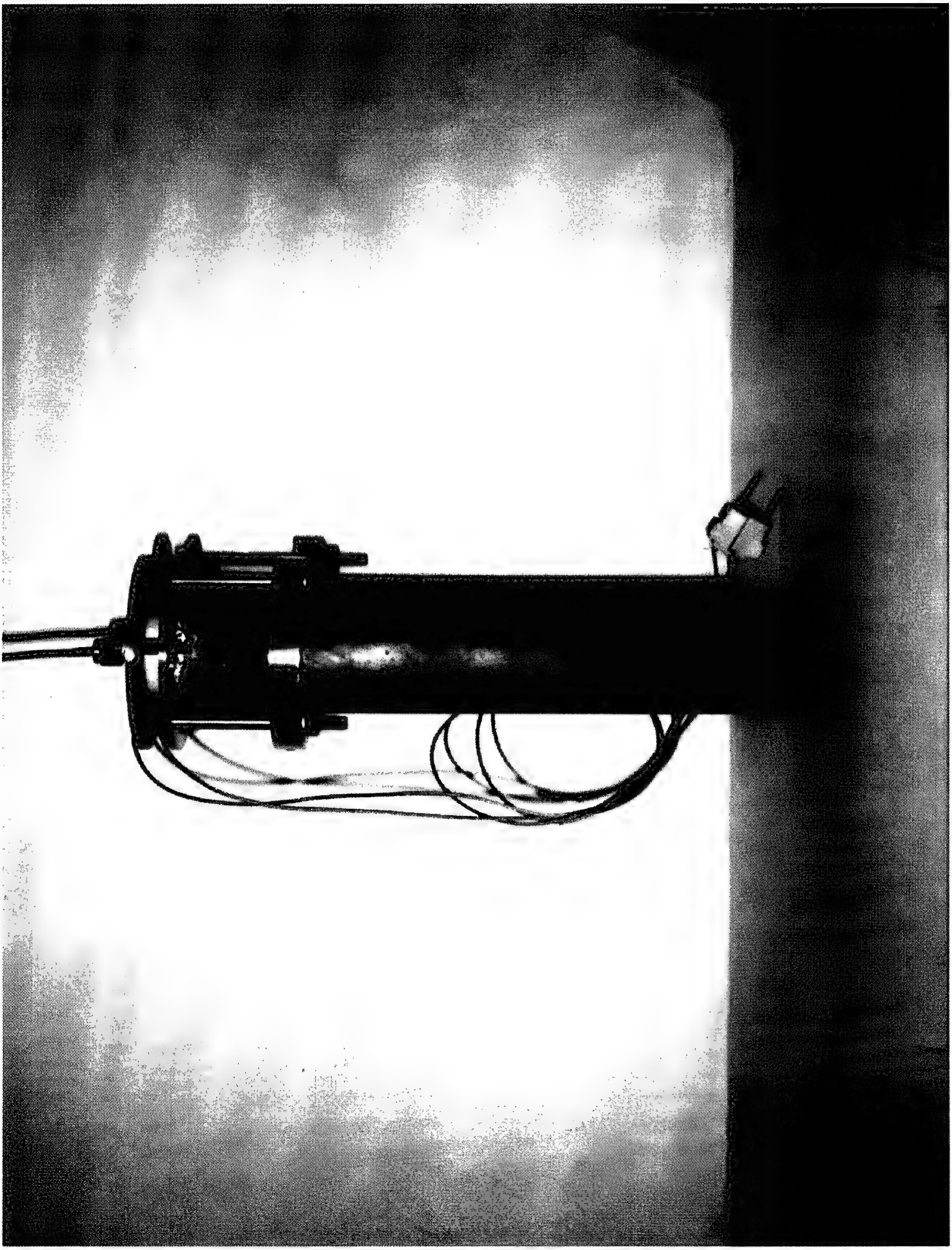
Actuator rods, like the one shown left, made of titanium matrix composite material have been selected for the preproduction version of the F-22's F119 engine. Design, manufacturing and maintenance experience obtained from this first application of titanium matrix composite material will enable its utilization in more demanding future Air Force aircraft applications.

Accomplishment

The Materials Directorate, working with the F-22 System Program Office, the Aero Propulsion and Power Directorate, Pratt and Whitney Aircraft, Parker Bertea Aerospace and Atlantic Research Corporation in a Wright Laboratory corporate program led by the Manufacturing Technology Directorate, has demonstrated a titanium matrix composite material that has been selected to replace stainless steel for the divergent nozzle actuator rods on the F119 engine of the F-22 aircraft. Mechanical tests have shown this composite material capable of withstanding the expected tension, compression, thermal and mechanical fatigue stresses that the rods will be subjected to.

Background

It is estimated that every 100 pounds of added weight equates to a loss of 1.4 miles from the range of the F-22 aircraft. Reducing the weight of individual parts while maintaining high performance levels is a prime objective, often achieved by making small incremental weight reductions in a large number of parts. One area for weight reduction on the F-22 is in the engine's aft section, where a system of flaps and seals make up an adjustable nozzle. Precision adjustment of the nozzle opening is controlled by a pair of hydraulic actuators with rods that extend and contract to position the flaps. The two rods must deliver precision performance through a range of severe operating conditions. For years actuator rods have been made of stainless steel, a dependable but heavy material. Replacing stainless steel for the actuator rods with the lighter (40 percent) titanium matrix composite material reinforced with continuous silicon carbide fibers will result in a weight savings of 7.4 pounds per aircraft. Future Air Force applications for this material could include actuator rods for ailerons, flaps and landing gear components. In turbine engines, the material could be used as reinforcement for hollow fan blades, as bladed compression rings or disks, and as shafts and cases.



Carbon-Carbon Composite Allows Use Of More Efficient, Lighter Batteries For Space Systems

Payoff

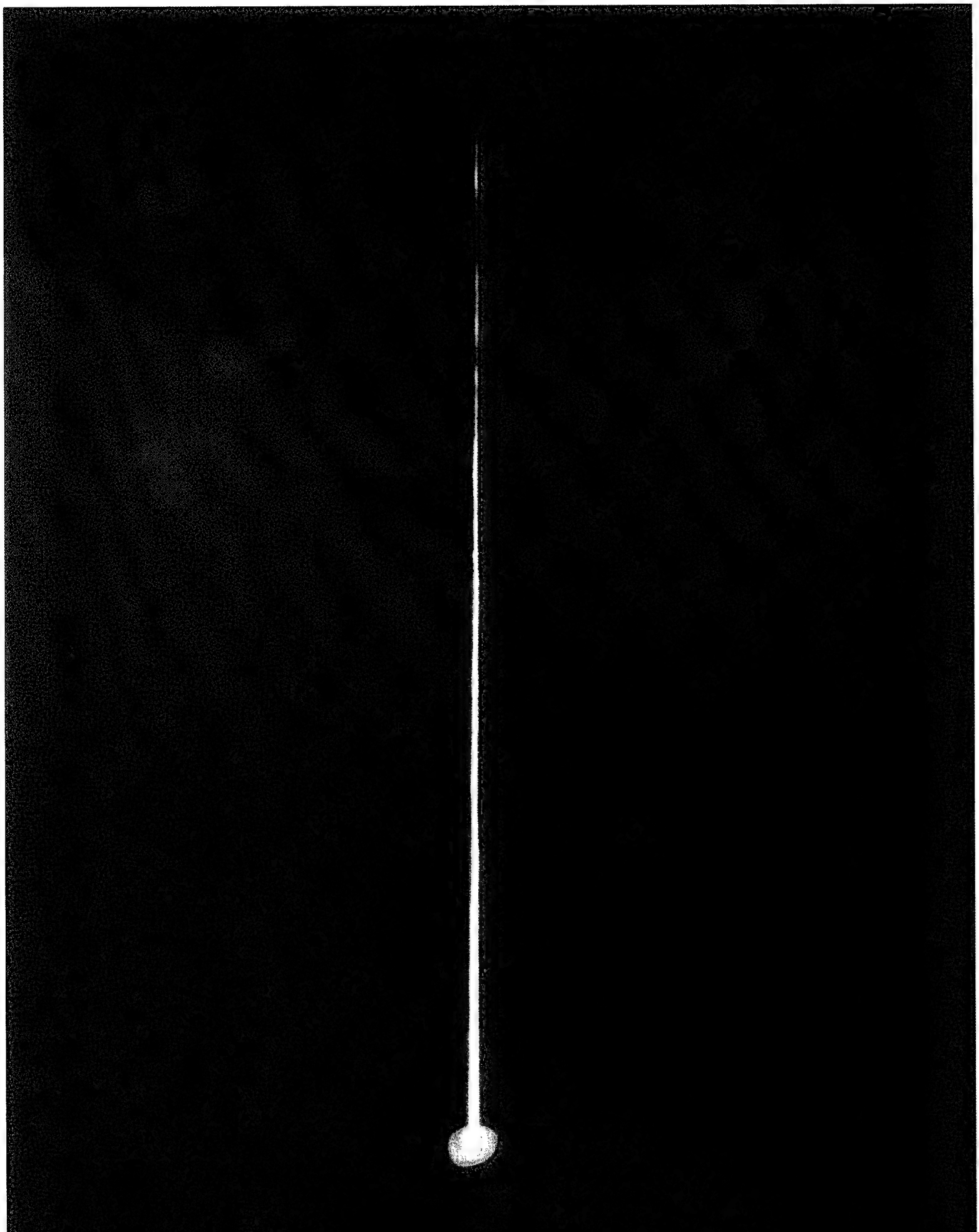
Carbon-carbon (CC) composite containers will allow the use of lighter, more efficient sodium-sulfur batteries in large, complex space power systems. These batteries can achieve up to three times the power increase at fixed battery weight, or a 67 percent reduction in battery weight at fixed power. These economies can reduce satellite launching costs and permit smaller, less expensive launch vehicles.

Accomplishment

Materials Directorate researchers, working with Materials and Systems Research, Inc. of Salt Lake City UT and coordinating with Phillips Laboratory, developed a new type battery container capable of housing a sodium-sulfur battery that resists corrosion and denting and also acts as a current collector. Using a carbon-carbon composite material developed by the Directorate, the container makes possible the application of a battery that can provide as much as 400 percent more power efficiency (200Wh/kg vs 50Wh/kg) than conventional batteries.

Background

Since electrical power systems make up a major part of a spacecraft's weight and batteries are typically the largest component of the power system, it is critical to improve the efficiency of spacecraft batteries. Battery efficiency is measured in terms of specific energy, or watt-hours of energy output per kilogram of battery weight (Wh/kg). Nickel-cadmium rechargeable batteries, the mainstay in space application for over two decades, can deliver specific energy only in the range of 7 to 50 Wh/kg. Sodium-sulfur batteries have been developed that can deliver a specific energy performance level up to 200 Wh/kg, but a successful container is a key challenge. Current sodium-sulfur batteries with steel containers are limited to a specific energy performance level of 75Wh/kg. These containers, even with protective coatings, can be easily dented or scratched, leading to corrosion and rapid failure. Materials and Systems Research, Inc., developed carbon-carbon containers that exhibit outstanding performance in several key areas. Resistance to corrosion is assured by excellent stability in the presence of molten sulfur and sodium polysulfides. Excellent strength and rigidity prevents the denting which leads to premature failure. These containers offer good electronic conductivity and excellent thermal conductivity for efficient heat removal to prevent cell overheating. Batteries were tested at temperatures up to 350°C through a range of discharge/charge cycles and freeze/thaw cycles. No failures occurred, and no corrosion or damage to the carbon-carbon container was observed in any of the tests. While Phase I testing determined the feasibility of carbon-carbon as a container for sodium-sulfur batteries, Phase II testing will determine the most efficient container production process. Phillips Laboratory will test the complete battery system delivered as a result of Phase II.



Waveguide Laser Combines Small Size, Precision Operation And Lower Cost

Payoff

Compact waveguide lasers that operate in the blue region of the visible spectrum offer high-precision capability for a broad range of Air Force and commercial opto-electronic applications, such as complex data transmission and interpretation. The simplified construction of the waveguide laser offers cost reductions of up to 85 percent over conventional red-emitting compact lasers and up to 20 percent over light-emitting diode lasers.

Accomplishment

Development of a lightweight waveguide laser less than one inch in length is the result of a collaborative Small Business Innovation Research effort between the Materials Directorate and Laser-Matter Laboratories of Albuquerque NM. Their laser, uniquely configured from a doped polymer, produces a blue-colored beam that offers higher resolution with a shorter wavelength than red lasers, so that the beam can have sharper and more accurate definition.

Background

Across the visible light spectrum, the color red has the longest wavelength; blue has the shortest. A shorter wavelength is necessary to overcome diffraction limitations and produce high precision light transmission. Red lasers, for example, can scan bar codes on food packages; while blue lasers can scan images that are 90 percent smaller and more intricate. While lasers in the Air Force today are used for range finding, weapons tracking, optical countermeasures, communication networks, remote monitors and a host of other offensive and defensive applications, there are many more uses. These include small lasers for data storage, compact disk reading, printing, xerography, communications and flat panel displays. Until now, low-cost lasers for these applications have been capable of operating only in the red region of the visible light spectrum, which means their accuracy is limited. Presently available blue lasers utilize argon gas-filled tubes or crystals as the lasing medium, or long fiber waveguides, with the result that they are costly, have limited life or are big and bulky. As light is directed through the new waveguide laser, a low degree of scattering produces a laser beam of remarkable purity at higher intensities. The devices lasing waveguide is made of a special polymethylmethacrylate (PMMA) thermoplastic polymer on an integral silicon oxide/silicon base, which results in light weight and easy integration into optical circuits. It is a very compact unit, typically measuring less than one inch in length, so it can fit into cramped spaces. A future application for blue waveguide lasers is in optical computing, where instead of hard wiring to transmit electrical signals, waveguide channels will transmit light beams.

Improved Crystal Growth Technique Provides More Reliable Laser Source

Payoff

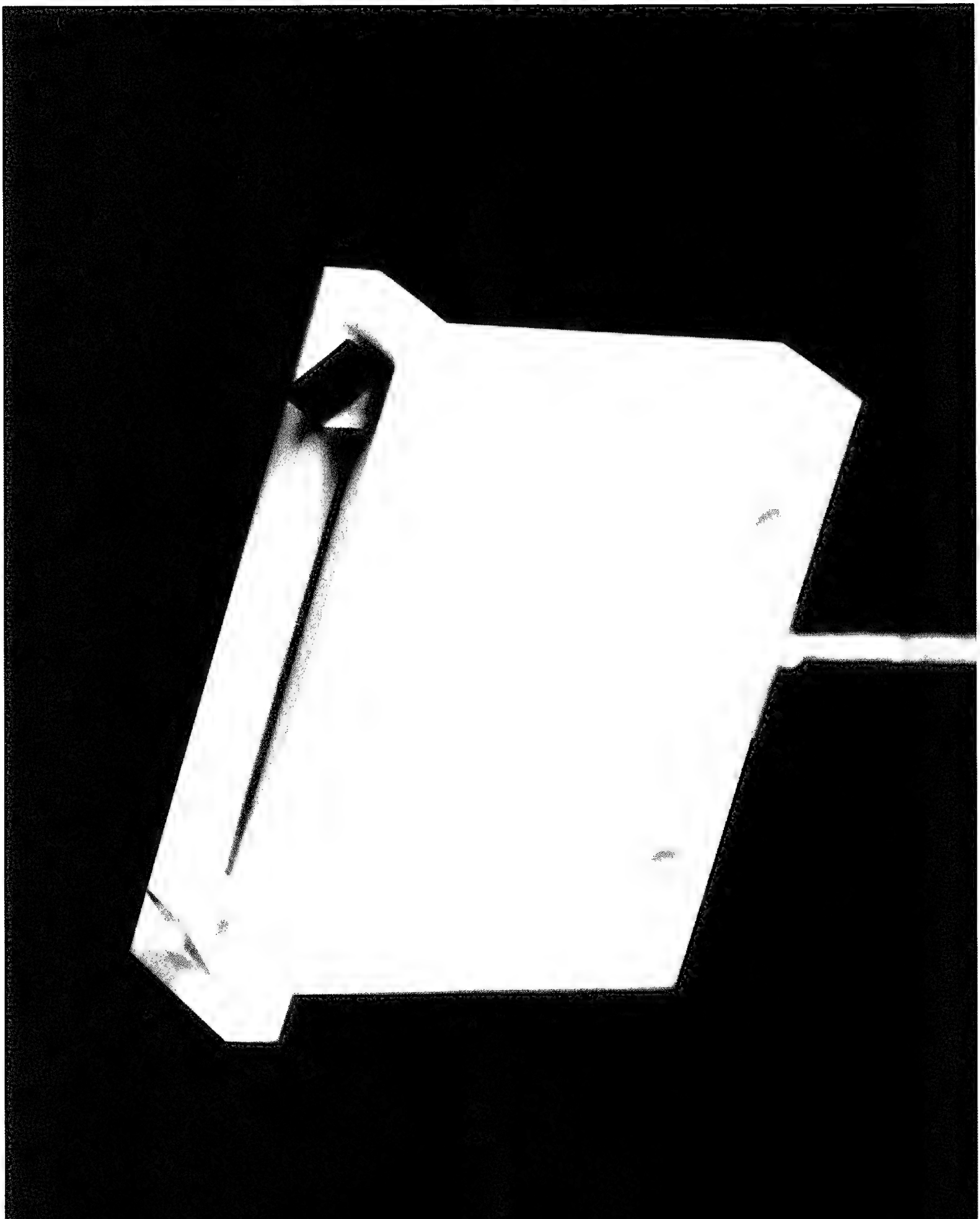
The improved crystal growth technique will produce potassium titanyl phosphate (KTP) crystals that are lower in cost and more reliable than traditional KTP crystals for lasers in the visible and near-infrared spectral regions. Their improved reliability permits higher power operation, which leads to the availability of large-aperture KTP crystals for laser-based satellite sensing systems, airborne countermeasure systems, projection television, medicine and other applications that require lasers with high-average power.

Accomplishment

Scientists at the Materials Directorate and Crystal Associates Incorporated jointly developed an improved growth technique which produces large-aperture nonlinear optical KTP crystals used in neodymium doped yttrium aluminum garnet (Nd:YAG) lasers. Their improvement eliminates the formation of local discolorations (gray tracks) that gradually develop when the laser beam passes through the KTP crystal, forming an area of light absorption.

Background

Many solid state lasers in use today for military, medical and industrial applications are made of Nd:YAG, a material that generates a laser beam with a fixed wavelength of about one micron. To increase the power and wavelength variability of these popular lasers, KTiOPO4, or KTP crystals are used. KTP crystals offer proven dependability, capability, high quality and low cost in scores of laser applications. To be effective, laser light must be transmitted without scattering or absorption, either of which absorb the laser's power and weaken the laser beam. A problem that has plagued KTP crystals since their introduction is a phenomenon called gray tracks. A possible solution to this problem was to develop new crystalline materials, a costly and time-consuming effort. Scientists at Crystal Associates Incorporated of Waldwick NJ, receiving financial support through the Small Business Innovation Research Program and technical support from the Materials Directorate's Nonlinear Optical Materials Characterization Facility found a direct solution to the gray tracks problem. They took a systematic approach to find a correlation between the causes and the nature of the gray tracking. From this effort, they developed an improved crystal growth technique which reliably and consistently produces large-aperture KTP crystals at a lower cost than traditional crystals. In a standardized laser test system capable of inducing gray track damage on ordinary KTP crystals, crystals produced using the new growth technique could not be damaged even after 10,000 shots at power densities several times higher than the operating range of ordinary Nd:YAG lasers.



New Laser Particle Counter Sensor Improves Semiconductor Device Yields

Payoff

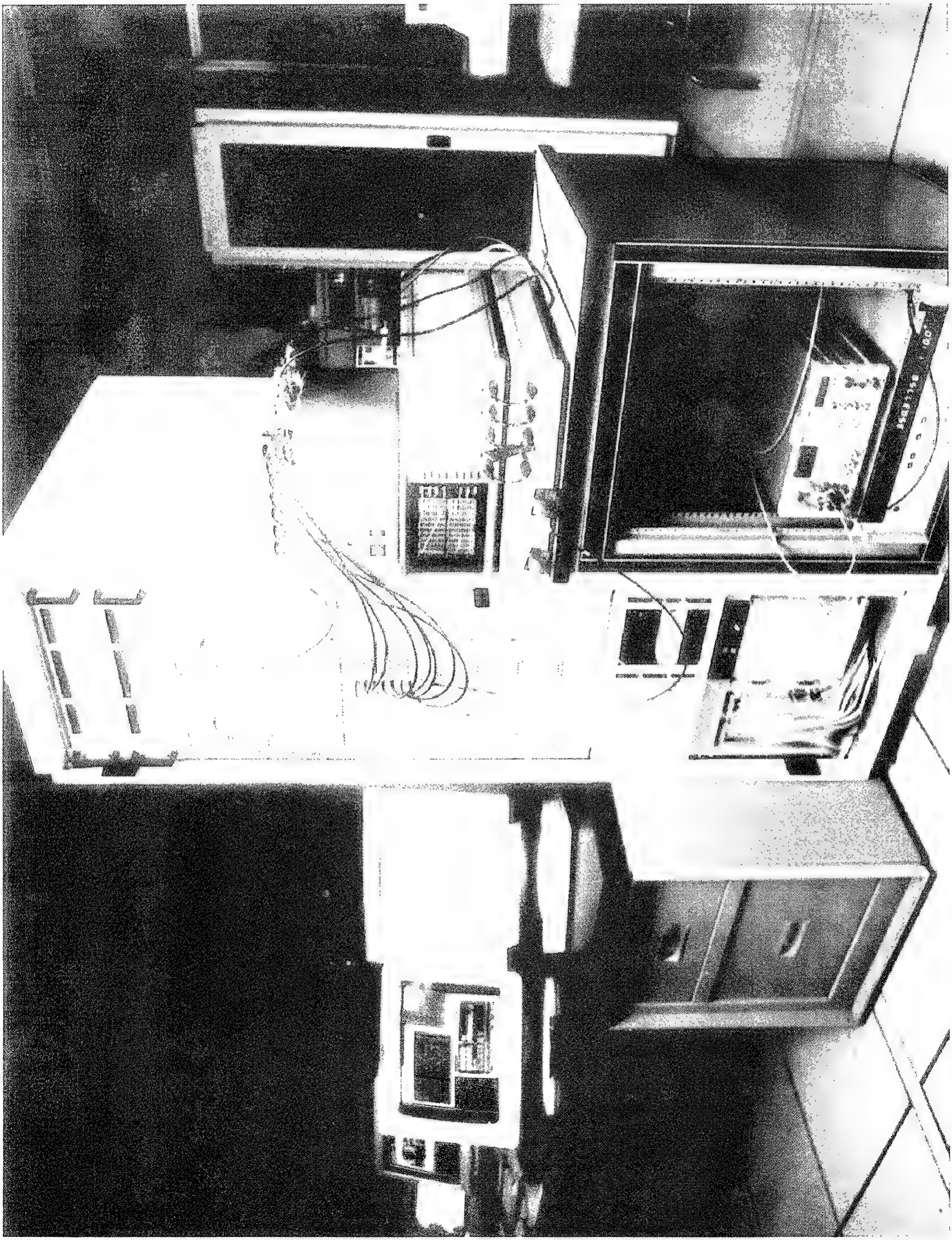
Using the laser particle counter (LPC) system probe, shown above, to monitor particle contamination in real time inside a variety of semiconductor process machines will enable equipment operators to obtain improved device yields. The LPC sensor system's capability to detect particle contaminates as small as 0.08 microns in semiconductor process equipment will result in a significant reduction in manufacturing defects on small feature semiconductor devices.

Accomplishment

Under a program sponsored by the Manufacturing Technology Directorate, a LPC system using state-of-the-art optical and electrical components was designed, fabricated and demonstrated. This LPC sensor system, for detection of particle contamination in real time within semiconductor process equipment, is able to detect particles as small as 0.08 microns inside a variety of semiconductor process machines.

Background

Electronic components in weapon systems are becoming more complex and denser in packaging. To meet future mission requirements, there is a continuing need to reduce size and weight of electronic components. With the feature sizes in semiconductor integrated circuits (ICs) becoming smaller as IC density increases, defects caused by small particles in the semiconductor process environment are becoming more of a problem. In the past, when these features had sizes of about several microns, 0.3 micron particles did not pose as large a problem to device yield as they presently pose for 0.5 micron features. Particulate contamination inherent in the manufacture of new advanced ICs increases product cost. One of the major sources of manufacturing defects on small feature, state-of-the-art devices is contamination from particulates generated within the IC fabrication equipment. Previously, high levels of small particles inside the process equipment itself were not thoroughly addressed. Such particles can be formed in the process equipment by sputtered or etch materials that dislodge from the vacuum chamber as it is evacuated or brought up to ambient pressure. New in-situ sensors and control techniques were needed to provide methods to control the semiconductor manufacturing process to improve device yields. The application of advanced laser and fiber-optic techniques to on-line particle monitoring in the process chamber was developed by Honeywell Sensor and System Development Center and successfully demonstrated in a Perkin Elmer 4400 sputtering machine. The LPC system's materials and design are compatible with high temperature vacuum, radio frequency and corrosive environments of existing semiconductor process equipment. It has built in diagnostic and automatic sensitivity adjustments for aging or process damage.



Antenna Wavefront Simulator (AWFS) Addresses Current and Future Antenna Electronics Systems

Payoff

The AWFS enables both industry and the Department of Defense (DoD) to identify and correct, if necessary, any potential Global Positioning System pitfalls with respect to receiver vulnerability, accuracy and performance prior to insertion in DoD systems. An enhanced version of the AWFS will simulate real-world moving jammers and platforms and save an estimated $20 million per test in test and evaluation costs.

Accomplishment

The Avionics Directorate's Navigation and Information Transmission Branch developed the world's first radio frequency Antenna Wave Front Simulator (AWFS) specifically designed to evaluate current and future antenna electronics (AE) in both a static and dynamic jamming environment. This unique capability is used to explore both military and commercial Global Positioning System (GPS) receiver technologies associated with GPS jamming susceptibility, integration issues, improved precision accuracy and controlled access on the battlefield.

Background

One of the key cornerstones of the exploration of GPS receiver technologies is to evaluate the current and future antenna electronics, as their performance directly impacts overall GPS receiver capability. The AWFS basically simulates a null-steering seven-element array Controlled Reception Pattern Antenna (CRPA) from which an ideal RF wavefront is generated and fed to an AE box followed by a GPS receiver. By its very nature, this innovative simulator has several key advantages over the traditional research environment (e.g., an anechoic chamber and flight testing) as it is repeatable, relatively low cost to implement and flexible in terms of platform dynamics and the multiple jammer types. The AWFS can also be reconfigured to support critical antenna beam-steering experiments that evaluate GPS performance against multiple jammers. Members of the GPS user community such as the GPS Joint Program Office (JPO), the National Air Intelligence Center and the F-117 System Program Office have commended performance results obtained using the AWFS. Additional members of the GPS user community have expressed keen interest in using the AWFS for evaluation of the Anti-jam GPS Technology Flight Test (AGTFT) System, the next generation AE-1 upgrade (AE-1A) and the GPS Antenna System (GAS).

Flow Field Enhancers Improve Aircraft Controllability

Payoff

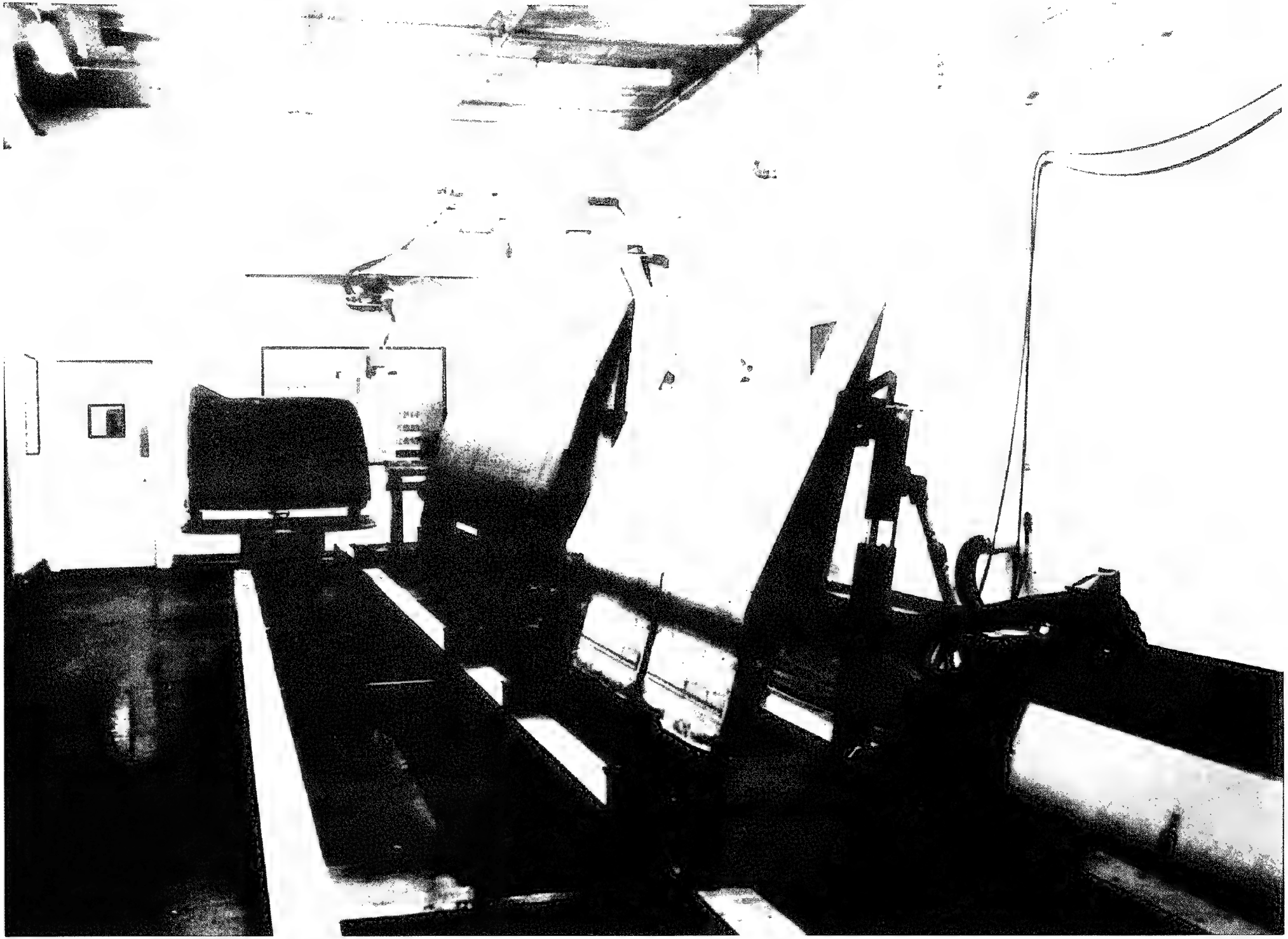
A set of pneumatic and mechanical maneuvering devices that can be used as flow field enhancers will improve controllability for advanced fighter aircraft configurations. These devices, evaluated in wind tunnels at realistic speeds and sizes, could increase maneuverability for next generation fighters by 15 percent and increase nose pointing ability by 25 percent, giving pilot advantage in maneuvering during aerial engagements.

Accomplishment

The Flight Dynamics Directorate's Aeromechanics Division's investigation of flow field enhancers indicated that enhancers represent an effective way to control forces and moments induced by an aircraft maneuver. Using two innovative types of forebody vortex control augmentation developed by the Directorate, vortices were used directly as an alternate source of high angle of attack control.

Background

The Flight Dynamics Directorate initiated a Fighter Lift and Control program to investigate forebody devices that show potential for enhancing the maneuver performance of advanced, low observable class fighter aircraft that have a chined forebody. Design of Experiments methodologies were applied to aid in selecting the most promising devices from the large number considered. Two types of forebody vortex control augmentation were investigated during eight wind tunnel tests using 3 percent to 55 percent scale models. One device is mechanical and uses forebody strakes, while the other device is pneumatic and uses forebody blowing to enhance maneuverability. Modern and advanced fighter aircraft are required to operate in a flight regime that requires the maximum maneuverability and controllability possible for effectiveness in the combat arena. Geometries that have been designed with low observable requirement have shown an aerodynamic penalty in the aircraft maneuver performance. Requirements for high maneuverability necessarily dictate that aircraft must fly at high angles of attack where aerodynamics are dominated by separated and vortex flows. These flows can induce or exacerbate adverse control characteristics such as wing rock, loss of yaw and roll control and uncontrolled pitch-up. One method to overcome these adverse control effects is the use of thrust vectoring. Mechanical thrust vectoring is quite effective, but additional weight and system complexity are a penalty. Instead of relying upon thrust vectoring to overcome the forces and moments induced by a maneuver, a more effective way to control these effects and enhance the aircraft controllability is to directly use the vortices as an alternate source of high angle of attack control.



Aircraft Robotic Paint Stripping System Protects Environment

Payoff

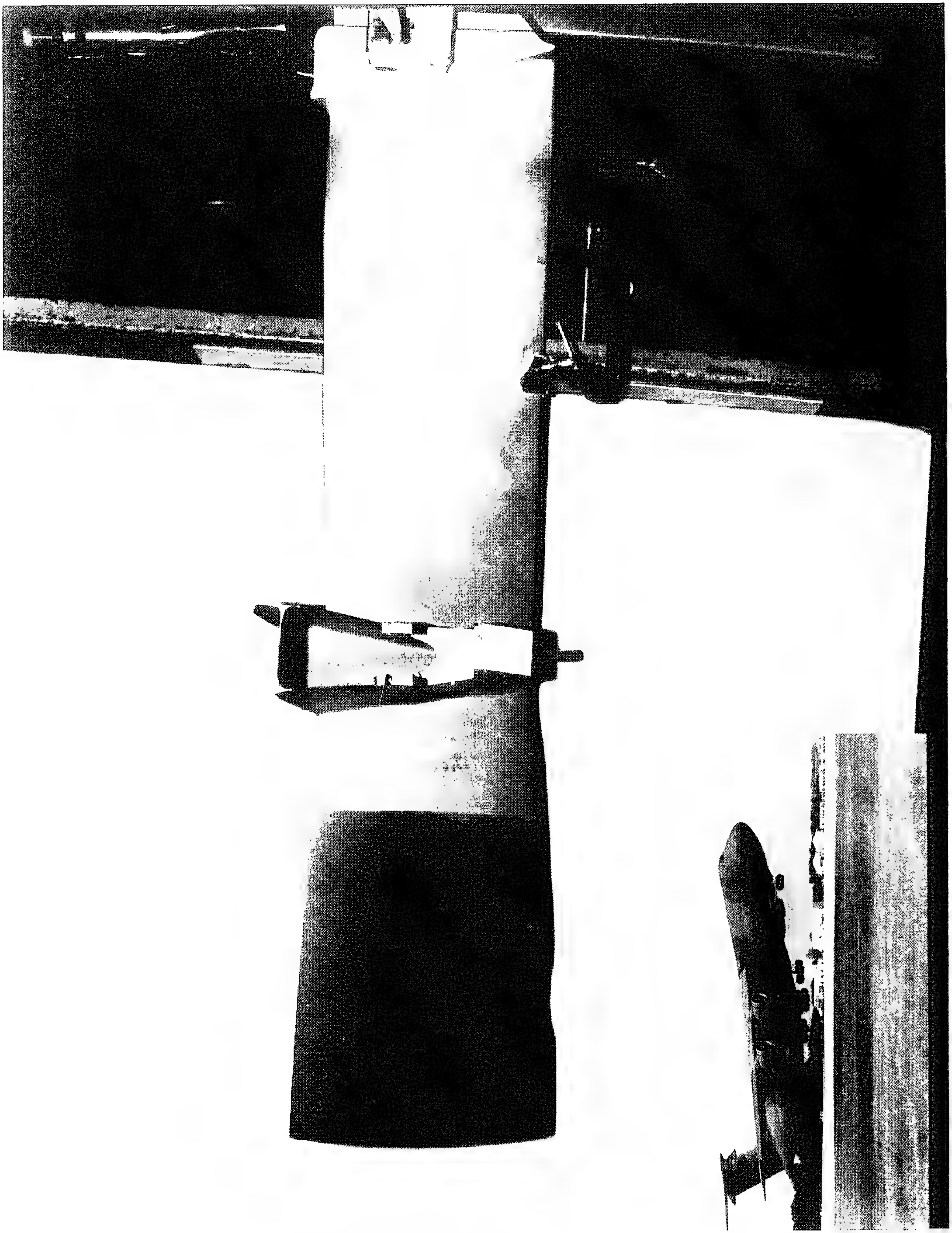
The deployment of a robotic high-pressure water paint stripping system will protect the environment by eliminating the use of toxic stripping chemicals and reducing hazardous waste produced by 94 percent. In addition to removing personnel from a hazardous environment, manhours for paint stripping will be reduced by 50 percent.

Accomplishment

Under a program sponsored by the Manufacturing Technology Directorate, United Technologies Corporation developed an automated paint stripping system that has been transitioned to the Oklahoma City Air Logistics Center (OC-ALC). This system uses a high-pressure water process which does not damage thin-skinned aircraft surfaces.

Background

The Large Aircraft Robotic Paint Stripping (LARPS) Program was initiated in 1991 to establish an automated low-cost environmentally safe paint removal system for aircraft and aircraft components at OC-ALC. One of its eight contract line items was the Aircraft Component Subsystem (ACS), a 50 ft x 20 ft paint stripping cell at OC-ALC. It provides automated, high-pressure water coatings removal for components that are removed from the aircraft. About 285,000 square feet of aircraft components are stripped annually at OC-ALC. Parts as large as the B-52 inboard flap measuring 31 ft x 8 ft can be stripped in this work cell. It is a self-contained, high-pressure, environmentally safe coatings removal system that keeps personnel out of a hazardous work environment. The LARPS Program was modified to also include a joint initiative line item with the Navy. Under this effort a high-pressure water coatings removal process in a naval shipyard was demonstrated and employed to remove coatings from ships and submarines in dry dock. The Navy's system uses a 6-inch nozzle designed to remove extremely thick coatings of paint from steel surfaces. It is portable with full recovery of contaminant at the source and has demonstrated stripping rates from 100-175 square feet per hour.



TF39 Engine Fan Blade Analysis And Repair Could Save Millions

Payoff

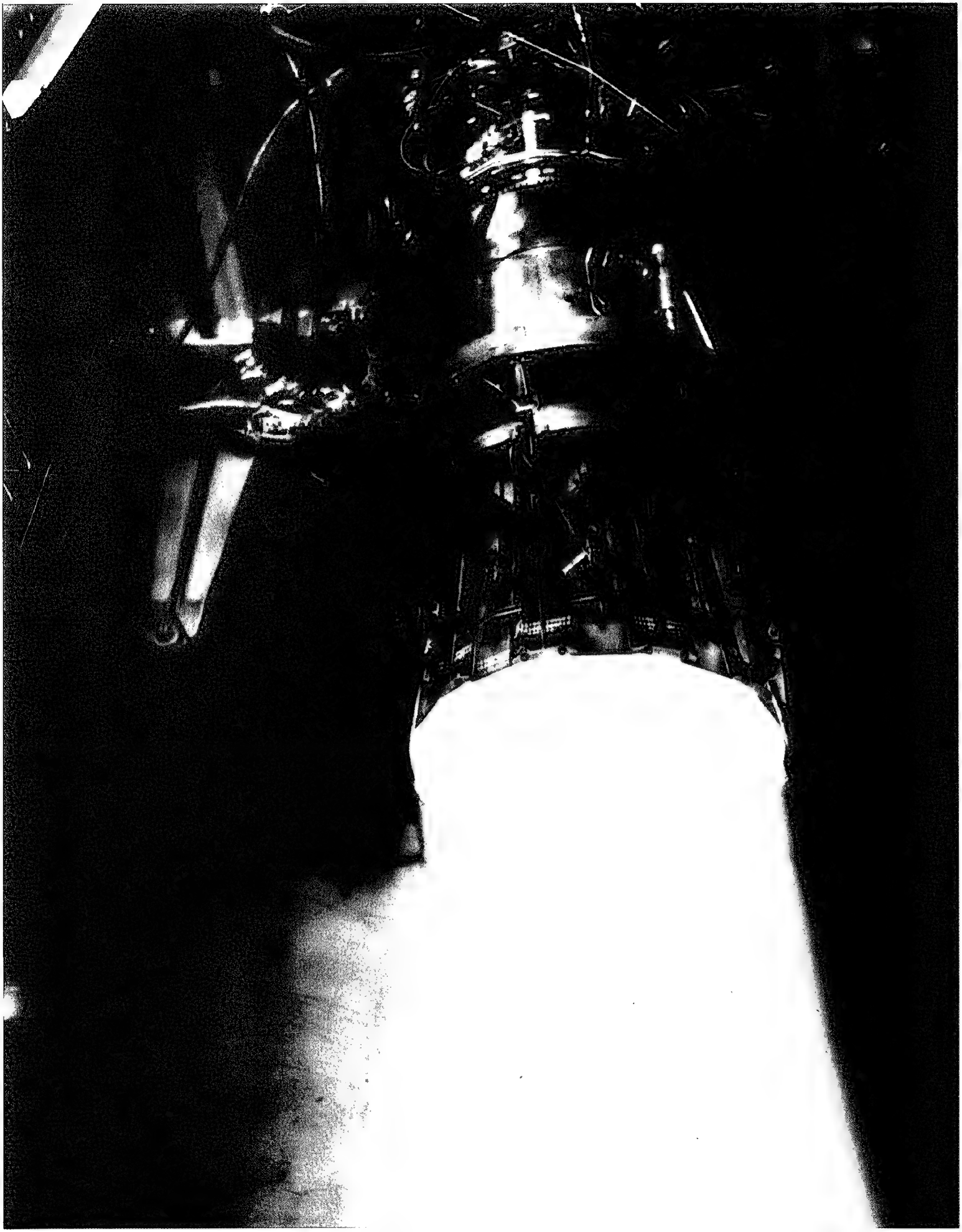
The repair procedure developed under a joint effort led by the Materials Directorate and San Antonio Air Logistics Center will significantly reduce the risk of costly engine damage caused by the failure of current second stage C-5 TF39 engine fan blades. Its implementation could save the Air Force $300 million over the cost of acquiring new blades and more than 5,000 man-hours required for non-destructive inspection of current fan blade spans.

Accomplishment

Engineers at Wright Laboratory's Materials Directorate assisted San Antonio Air Logistics Center (SA-ALC) personnel in analyzing and solving a cracking problem in second stage fan blade interlocks of the C-5's TF39 engine. This joint effort resulted in the development of key repair processes in a $30 million modification program of the fan blade's mid span.

Background

Even with the introduction of the new C-17 aircraft, the C-5 will be a mainstay for years to come. Sustaining these aircraft will require the repair and replacement of various components that will exceed their original design life. These actions will take place in modification or update programs or after the discovery of a problem during normal use. A cracking problem discovered in the second stage fan blade interlocks of TF39 engines on C-5A/B aircraft resulted in 12 critical fan blade failures. One such failure led to a blade separation and destruction of an entire engine. Two other failures resulted in fuselage penetration by uncontained debris. The Materials Directorate specialists, following an extensive evaluation of the failures, identified the problem as fatigue cracking in the high stress area of the mid-span blade interlocks. Working with the SA-ALC, General Electric and Praxair in Kansas City MO, they assisted in designing a repair procedure to avoid fan blade failures. The repair process includes grinding out the high stressed area (approximately 2 in. x 3 in.) from the interlock, forging a Ti 64 insert, electron beam (EB) welding the insert into the open interlock, and machining the blade back to original dimensions. Since poor EB welds, if undetected, could cause similar failures of equal or greater magnitude to those already occurring, Materials Directorate engineers performed an in-house analysis to qualify the repairs for both General Electric and Praxair. The repair program includes the implementation of the suggested repair procedure to 210 blades on actual TF39 engines.



New Composite Material Provides 900 Percent Increase In Operational Life of Aircraft Afterburner Nozzle Components

Payoff

The use of the high-performance silicon carbide-reinforced carbon material in the shape of an augmentor nozzle seal (shown glowing red left) on the F414 engine for the Navy's F-18 is necessary, since metal components fall far short of performance requirements. Ceramic matrix composites can easily meet the operational life requirements of afterburner nozzle flaps and seals in advanced, high-temperature turbine engines, and are expected to achieve significant life cycle cost savings over conventional flaps and seals.

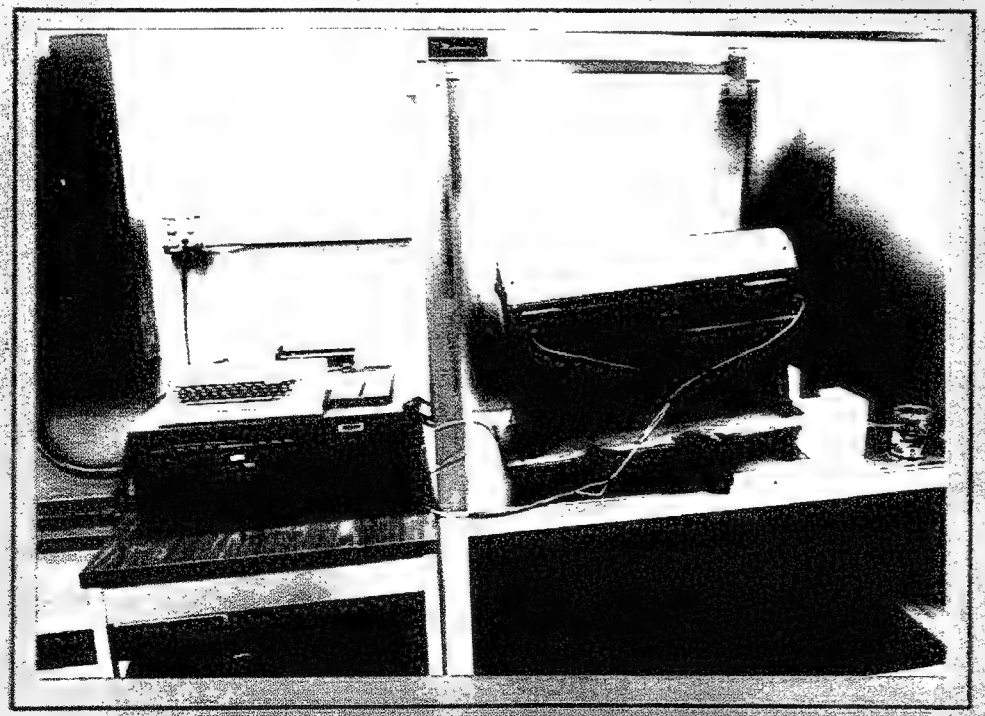
Accomplishment

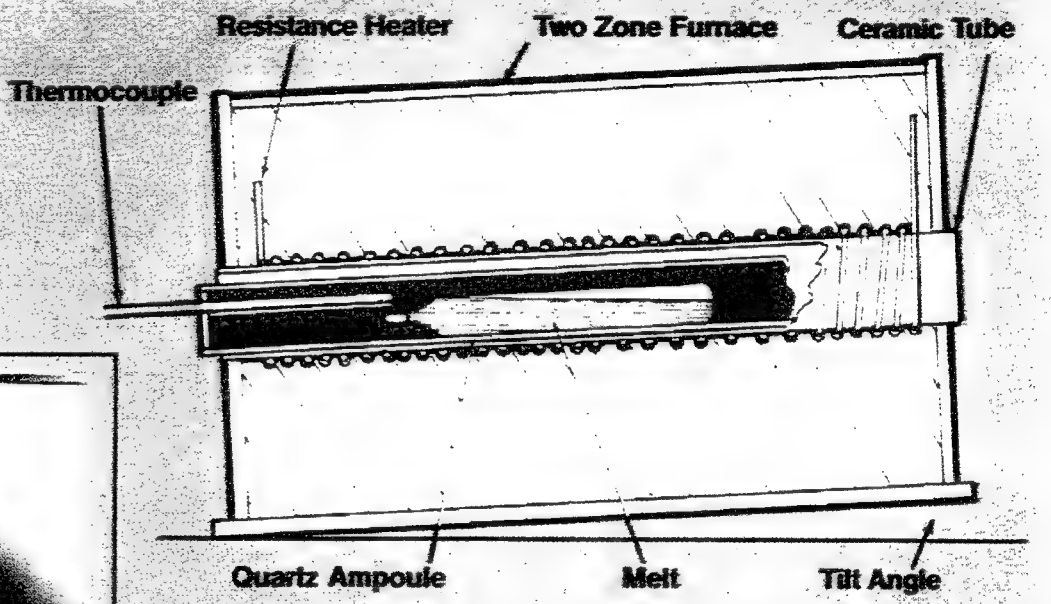
Composite technology developed by Wright Laboratory's Materials Directorate has been utilized to achieve a 900 percent increase in the operational life of afterburner nozzle components on aircraft turbine engines. The ceramic matrix composite material that combines silicon carbide continuous fibers in an inhibited carbon matrix can withstand the extreme thermal, mechanical and acoustic environment in high-performance engines.

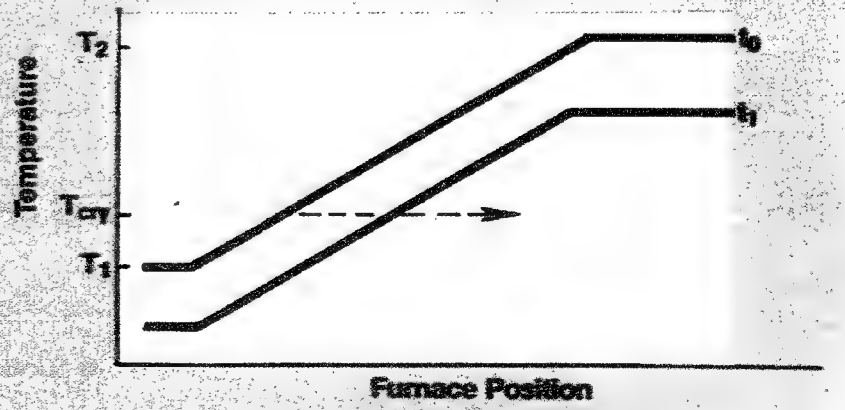
Background

Military aircraft powered by turbine engines use afterburners when a quick-response power boost is needed. To augment this boost, a system of flaps and seals make up an adjustable nozzle that can partially close to intensify the velocity of the exhaust. While temperatures of conventional turbine engines are low enough to permit use of nickel-based superalloy flaps and seals, today's advanced engines with greater thrust operate at temperatures beyond the capability of superalloys. Metal components tend to warp, crack and fail after only one-third of their design life, effectively grounding the aircraft until repairs can be made. A carbon-carbon matrix material was developed several years ago by the Materials Directorate and Hitco, Inc. of Gardena CA, and was tested in a General Electric engine at Evendale OH. The silicon carbide fibers provide tensile strength and durability, while maintaining a close match in coefficient of thermal expansion with the matrix. The matrix offers stiffness and temperature resistance, and a silicon carbide coating protects against oxidation. Besides outstanding heat resistance, ceramic matrix composites are extremely damage-tolerant, and offer increased toughness over monolithic ceramics. These flaps and seals provide a 900 percent operating life improvement over metal components. The first application for ceramic matrix composite flaps and seals is in the F414 engine upgrade. This engine is under development by General Electric, Lynn MA, who adapted the technology from General Electric - Evendale, for installation in the Navy F-18 Hornet aircraft. The success of the F414 program has resulted in an ARPA-funded program to develop the first structurally-designed oxide-oxide ceramic matrix composite flaps and seals for afterburner nozzles on the Air Force F110 engine family for the F-16. Life cycle cost savings for the F110 engine are expected to reflect substantial savings. Engine tests are scheduled during mid-1995.

Growth Configuration for Horizontal Gradient Growth







Acronym List

Acronym	Definition
2D	Two-Dimensional
AC	Alternating Current
ACS	Aircraft Component Subsystem
AE	Antenna Electronics
AE-1A	AE-1 Upgrade
AFFF	Aqueous Film Forming Foam
AGTFT	Anti-Jam GPS Technology Flight Test
AMC	Air Mobility Command
ANG	Air National Guard
AWFS	Antenna Wavefront Simulator
ARDEC	Armament Research, Development and Engineering Center
ARPA	Advanced Research Projects Agency
C-C	Carbon-Carbon
CDP	Career Development Program
CDRA	Cooperative Research and Development Agreement
CMC	Ceramic Matrix Composite
CRPA	Controlled Reception Pattern Antenna
CVD	Chemical Vapor Deposition
DC	Direct Current
DMS	Desorption Mass Spectrometry
DoD	Department of Defense
EB	Electron Beam
ELITE	Extended Long-Range Integrated Technology Evaluation
ELMS	Electrical Load Management System
EPCRA	Emergency Planning and Community Right-to-Know Act
FAA	Federal Aviation Administration
FIGPB	Fuzed, Insensitive General Purpose Bomb
GaAs	Gallium Arsenide
GAS	GPS Antenna System
GaSb	Gallium Antimonide
GC	Gas-Chromatograph
GPGS	Ground Power Generation System
GPS	Global Positioning System
HBT	Heterojunction Bipolar Transistor
HSAP	High School Apprenticeship Program
IC	Integrated Circuits
IDEF	Integrated Computer-Aided Manufacturing DEFinition
IHPTET	Integrated High Performance Turbine Engine Technology
IMU	Inertial Measurement Unit
JDAM	Joint Direct Attack Munition
JETEC	Joint Expendable Turbine Engine Concept
JPO	Joint Program Office
KTP	Potassium Titanyl Phosphate
LADAR	Laser Radar
LARPS	Large Aircraft Robotic Paint Stripping
LHMEL	Laser Hardened Materials Evaluation Laboratory
LIMO	Linear Motion Oven
LPC	Laser Particle Counter
MBE	Molecular Beam Epitaxy
MMIC	Microwave Monolithic Integrated Circuit
MOCVD	Metal-Organic Chemical Vapor Deposition
MOFA	Multi-Option Fuze for Artillery
MOMBE	Metal-Organic Molecular Beam Epitaxy
MWCVI	Microwave Chemical Vapor Infiltration
Nd:YAG	Neodymium Doped Yttrium Aluminum Garnet
NSC	National Semiconductor Corporation
OC-ALC	Oklahoma City Air Logistics Center
OCD	Operational Concept Demonstration
PACIS	Platform for the Automated Construction of Intelligent Systems
PCA	Propulsion Controlled Aircraft
PHEMT	Pseudomorphic High Electron Mobility Transistors
PMMA	Polymethylmethacrylate
PRF	Pulse Repetition Frequency
RLG	Ring Laser Gyro
RT	Remote Terminals

Acronym List

Acronym	Definition
SA-ALC	San Antonio Air Logistics Center
SBIR	Small Business Innovation Research Program
SLI	Semiconductor Laser International
SRI	Scanning Radiometric Imager
SSPC	Solid State Power Controller
TCAM	Thermochemically Actuated Motion
TRIT	Turbine Rotor Inlet Temperature
WR-ALC	Warner Robins-Air Logistics Center
ZGP	Zinc Germanium Phosphide

- **To receive more information from the experts involved in the "Success Stories" contained in this document, please call WL/DOR @ (513) 255-4119.**

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  - ☐ **Cooperative Research & Development Agreements**
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